Assessment of demand for electricity in the state of Gujarat in the short, medium and long run.

Final Report

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Assessment of demand for electricity in the State of Gujarat in short, medium and long run

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Executive Summary

This study, initiated by Gujarat Electricity Board, forecasts the demand for electricity in the state of Gujarat in the short (2002-03), medium (2006-07) and long (2011-12) run. An extensive literature survey has been done to study the documented experiences in various international and domestic demand forecasting studies. The literature survey was also helpful in deciding the various driving factors that were used in the forecast models as developed for the different sectors.

The total consumption has been segregated into consumption by the four major categories of consumers viz. agriculture, commercial, domestic and industry, which constitutes nearly 97 per cent of the total consumption. The rest of the consumption is classified under 'others'. This classification has been used throughout this study. The execution of the study has been done at two levels (Annex I) – on the basis of secondary data and primary data. Secondary data regarding consumption of electricity and the various factors affecting it were collated and analysed. Econometric models - both intensity and structural models – have been built for each sector and these have been used to obtain forecasts, which are then aggregated to arrive at the sectoral total consumption. To the sectoral total is added the consumption by 'other category' to obtain the total consumption of electricity in the state. The consumption by the 'other categories' is assumed to be at 3 per cent over the entire forecast period as obtained from the past time series data.

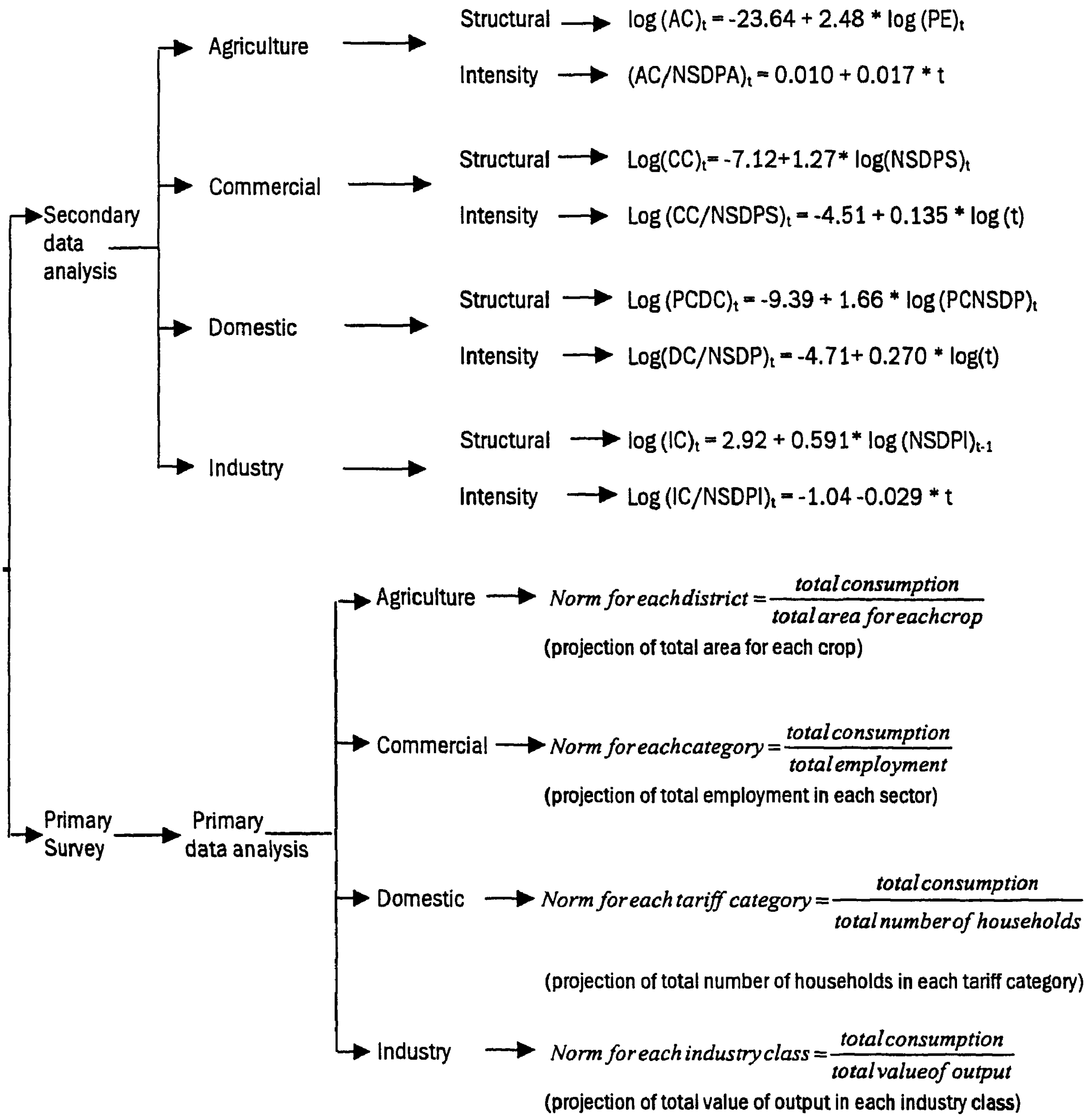
For the second level of forecasting exercise based on primary models, a consumer survey has been conducted in the state. A sectoral survey has been conducted with questionnaires developed specific to each sector, on the basis of sectoral models designed. The data collected therein has been analysed and consumption norms are developed for each sector which are used to forecast the consumption in each category and hence in the state. Various scenarios such as the effect of the technology, the effect of efficiency improvements, have been incorporated wherever possible.

To the total consumption figures thus obtained (under the various scenarios) for the state was added the transmission and distribution (T&D) losses as estimated on the basis of certain assumptions. The T&D loss assumption assumes a moderate decline after 2002-03 onwards, which was pegged at 26.84 per cent for the state. Thus loss in 2006-07 stands at 21.34 per cent and 2011-12, the loss is at 17.84 per cent. This aggregation provides an estimate of the total generation requirement at the busbar (excluding auxiliary consumption and the optimal spinning and other reserves). Applying the load factor as assumed in the Sixteenth Electric Power Survey, the peak demand in the system was calculated.

Thereafter the supply side analysis has been carried out. On the basis of the existing plants and future additions as provided by GEB and verified from the respective sources wherever feasible, the future installed capacity was arrived at. Applying the PLF (Plant Load Factor) norms and auxiliary consumption norms to the respective plants, the generation assessment in the different years has been made. Further, peak supply available with GEB is arrived by using CEA norms on net peaking availability factor (%) for the exiting and future GEB plants.

Annexure I

hart of the study



1 Introduction

1.1 Introduction

The need and relevance of forecasting demand for an electric utility has become a much-discussed issue in the recent past. This has led to the development of various new tools and methods for forecasting in the last two decades. In the past, straight-line extrapolations of historical energy consumption trends served well. However, with the onset of rapidly rising energy prices, emergence of alternative fuels and technologies (in energy supply and end-use), changes in lifestyles, institutional changes etc, it has become imperative to use modeling techniques which capture the effect of factors such as prices, income, population, technology and other economic, demographic, policy and technological variables.

In the present context, there is a need for precision in the forecasts for demand because of its strong financial implications. Today an underestimate could lead to under-capacity, which would result in poor quality of service including localized brownouts or even blackouts with subsequent impact on economic activities. An overestimate could lead to the authorization of a plant that may not be needed for several years, thus leading to a large sunk investment. Many utilities do not earn enough to be able to cover such a cost without offsetting revenues.

The gestation period for power plants, which are set up to meet consumer demand, typically varies between 7 to12 years in the case of thermal and hydro plants and 3 to 5 years for gas-based plants. As a result, utilities must forecast demand for the long run (10 to 20 years), to make decisions on the plant size or capacity as well as plans and decisions on investment, construction and conservation. From the perspective of the economy, since electricity is considered to be a basic indicator of economic development, the electric power sector has to keep pace with the demand of the consuming sectors. The electric utilities are therefore required to have a perception of the present as well as future requirement of each sector in the economy. Furthermore, like any other commodity, electricity demand is also influenced by the price of electricity and

alternative fuels. Thus incorporating the feedback effects of pricing and other fuel policy changes, helps in judging the current and future opportunities of inter fuel substitution.

Short-term demand forecasting, in particular, plays an important role in the process of regulation. A precise estimate of demand is important for the purpose of setting tariffs. A detailed consumer category-wise consumption forecast helps in the determination of future energy requirement based on which power procurement plans would be made by the utility. Moreover, power purchase is the largest component in the cost structure of the utility – a reliable estimate of the same is essential to determine the revenue requirement of the utility, which in turn facilitates in developing a just and reasonable tariff structure wherein no consumer pays less than the cost incurred by the utility for supplying the power.

This report provides a conceptual framework and the analytical methods and tools that could be useful in developing models of electricity demand. The study was initiated by Gujarat Electricity Board and Tata Energy Research Institute with the objective of forecasting the demand for electricity in the state of Gujarat in the short, medium and long run under different scenarios. Further, the supply of electricity as has been planned by the state is being assessed in order to have a perception of the demand-supply gap for the short run (2002-03), medium run (2006-07) and long run (2011-12).

2 Overview of Gujarat

2.1 Economy

The economy of Gujarat has grown rapidly in the recent past. The state income in FY1996-97 (at current prices) was 6.7% of the national income. Quick estimates of the net state domestic product show an increase of 5.8% in FY1998 over the previous year as given in the table 1.1 below.

The increase in the NSDP is mainly due to a high growth rate in the secondary and tertiary sectors. The secondary sector comprises manufacturing; electricity, gas and water supply. The tertiary sector comprises services sectors such as trade, transport, communications, ownership of dwellings, public administration, etc. In terms of sectoral trends, the growth in the secondary and the tertiary sector has far outpaced that in the primary sector. This has led to a structural shift in the economy from the primary sector toward the secondary

and tertiary sectors. Gujarat has, in recent years, shown a greater rate of growth than the national average and is considered one of the most industrialized states of the country. The following table 1.2 compares the rate of development of Gujarat with the respective national averages.

Table 1.1. Net state domestic product at 1993-94 prices.

Year	State Domestic Product (93/94 prices)	
	Aggregate (Rs. Lakhs)	Per capita income(Rs.)
1993-94	4256047	9796
1994-95	5110362	11535
1995-96	5262943	11649
1996-97	6065257	13206
1997-98	6027304	12937
1998-99	6377678	13493
1999-2000*	6244975	13022
2000-01*	6316144	12975

* Quick estimates

As shown in the table 1.2, Gujarat has performed better in terms of economic indicators in comparison with the all-India average. The percentage of literate population in the state is 61.3% and ranks ninth amongst the states of India. Further, as on 31st March 1998, 17996 out of the 18028 villages in the

Table1.2. Selected Economic Indicators.

Indicator	Gujarat	India
Literate population in 1991 (%)	61.3	52.2
Relative Infrastructure development Index (1992-93)	125.0	100.0
Per capita power consumption in 1994 (kWh)	520.0	270.0
%age of villages electrified (31 March 1997)	99.9	84.9
Share of manufacturing in NSDP (%) 1998-99	32.21	26.09
Share of services in NSDP (%) 1998-99	40.96	39.52

Source. Socio-Economic Review Gujarat State, 1998-99

Basic Statistics Relating to States of India: CMIE, September 1994

state have been electrified. The remaining 32 villages are not feasible for electrification. Thus all the feasible villages in the state have been electrified. The relative infrastructure development index of the state for 1992-93 also shows that the infrastructure in the state is better than the all –India average. The share of manufacturing and services in the net state domestic product in Gujarat was higher than that for India in 1998-99. In the recent past, Gujarat has experienced a structural shift in the economy with the share of the primary sector going down to 17.14% of the NSDP during 2000-01. The share of the

secondary and tertiary sectors has gone up to 35.99% and 46.87% of the NSDP in the same year.

1.2.2 Electricity sector

With the rapid growth in the industrial and services sector, the demand for electricity in the individual sectors has increased. On the other hand, due to a liberal captive power policy of the Government of Gujarat and the relatively easy access of oil and natural gas, Gujarat has witnessed an increase in the number of captive power plants. The demand supply scenario in the state is summarised in the table 1.3.

Table 1.3. Demand Supply scenario in Gujarat

Year	Installed capacity at the end of the year (MW)	Electricity generated in the year (MU)*	Total sale of electricity in the year (MU)**
1980-1981	2197	9363	7566
1990-1991	4395	19888	17255
1995-1996	5040	26115	27253
1996-1997	5307	27471	28289
1997-1998	6213	30643	29513
1998-1999^E	5760	26288	28209
1999-2000^E	6325	33039	30904
2000-2001^E	6325	37606	31666

* These figures are exclusive of those of diesel and wind power projects of the state as well as those of the central power projects

** Inclusive of sale of GEB and AEC only

^{E} Estimate as per the tariff filing for the respective year

The Central Electricity Authority on the other hand has compiled data on the energy requirement and energy available (actual) in the state in the last six years beginning 1996-97. As per the data available there has been energy deficit across all years with a rising trend in the last three years, which peaks in 2001-02 at 11 per cent. Corresponding data on peak demand and peak met is also available.

Table 1.4. Energy and peak deficits in Gujarat (1996-2001)

Year	Energy requirement	Energy availability	Energy deficit	Peak demand	Peak met	Peak deficit
1996-97	38225	35111	8%	6100	5151	16%
1997-98	40622	38489	5%	6367	5961	6%
1998-99	45685	42835	6%	7018	5877	16%
1999-2000	51202	46994	8%	7554	5962	21%
2000-01	53038	47877	10%	7801	6905	11%
20001-02	53693	47530	11%	8005	6760	16%

Source. CEA

In the peak data also, there are large deficits across the years, with a maximum of 21 per cent in the year 1999-00. The last year deficit stands at an alarming 16 per cent

This report provides a detailed analysis of the present situation of electricity demand and supply in the state of Gujarat as well as a prediction of the situation that might prevail 10 years down the line under assumptions of various possible scenarios. The scheme of the report is outlined below.

1.3 Chapter outline

A literature survey presented in chapter 2 was done to get an overview of the recent studies done to assess the demand for electricity in various countries. This international literature survey provides information on various methodologies adopted by researchers across the globe for demand forecasting exercise. The methodologies along with the associated drawbacks have been a useful guideline for the tools and techniques that could be adopted for this study.

The project has undertaken a sectoral demand analysis whereby four major electricity consuming sectors, viz., agriculture, commercial, domestic and industry have been considered. The current as well as future demand for electricity of each of these sectors have been estimated and forecasted. For all the sectors the entire exercise of forecasting demand has been executed at two levels namely, primary and secondary. At the level of secondary data analysis, discussed in chapter 3, demand for electricity has been related to macroeconomic indicators. Econometric modeling has been applied as a tool for establishing relationship between electricity demand and its various driving factors.

Further, a cross-sectional analysis has also been attempted based on data collected through a primary sample survey of individual consumers of the four identified sectors of the economy. The collected primary data have been optimally utilized for analyzing in detail the pattern of consumption at various levels of disaggregation within each consuming sector. Chapter 4 deals with the same.

Based on the findings of the primary survey data analysis of chapter 4, mathematical models have been developed for the purpose of forecasting

demand for electricity of each of the four identified sectors and the same has been described in detail in chapter 5, the primary model chapter.

Chapter 6 gives an overview of the supply side situation in the state. The supply side has been analysed in terms of the current generation capacity of Gujarat and the future capacity additions planned in the state.

In the final chapter of the report, chapter 7 , the results under the demand side and supply side scenarios have been collated on the basis of which an estimation of the supply/deficit situation in the state at present have been provided along with an indication of the future condition.

2 Literature survey

2.1 Introduction

Demand forecasting is an important task in power systems, since accurate forecasting results in an economic, reliable and secure power system operation and planning. Forecasting is necessary at long, mid and short - terms; the first two are necessary for generation planning, planning for expansion of transmission network, annual hydrothermal maintenance scheduling etc. Besides, investment planning is the other crucial objective of long term forecast. Since policy decisions with respect to investment issues are often tailored to demand needs, accuracy of these forecasts are therefore essential. The short-term load forecasting system on the other hand could be annual or daily projections for generation scheduling, security assessment and economic load dispatch. The daily projections are carried out by utilities for hourly dispatch and maintenance schedule design and the annual forecasts are necessary for power purchase plan and in recent times for tariff proposal. But even today, demand projection for the power sector is an intriguing exercise in India. The major lacunae in the exercise is availability of accurate data for forecasting.

2.2 Forecast methodologies

The methodology adopted for any forecasting exercise is dependent on the span of the 'forecasting period'. The approaches differ for a long, medium and short term forecast. In the short-term the demand forecasting method frequently used is trend analysis – where the past/ historic demand data is primarily used as the basis for projection. In the medium and long term, time series or regression modeling approaches are adopted. But these have certain inherent drawbacks in terms of possible numerical instability due to improper modeling. The other approaches include exponential smoothening, stochastic process, state space methods and expert systems. However these methods also fail to address some significant issues like, the relationship between the loads and certain specific variables that influence the load, namely, weather and holidays. The other difficulty lies in estimating and adjusting the model parameters. Traditionally, these parameters have been estimated from historical data, which ignores the

fact that the data could be obsolete or that it may not reflect the short-term load patterns. The introduction of artificial neural networking recently has partly taken care of the above shortcomings. It is used for accurate forecasting and the fuzzy expert system model deals with the variation factors arising due to holidays, temperature change etc.

The traditional approaches of forecasting include, forecasting from electricity data, the peak demand and then using forecasted load factors to decide annual demand (KWh).

(i) from electricity data, annual KWh by consumer class and summate, then using forecasted load factors to deduce KW peak demand.

(ii) from electricity data, peak load and annual KWh separately, checking derived load factors against past experience.

(iii) from national economic data, annual GDP and national energy, breaking down the latter into gas, electricity, oil etc and converting electricity KWh into KW using forecasted load factor.

The above forecasting exercises depend on a few tested methodologies extensively used for projection exercises in all areas, namely:

(a) Trend extrapolation - considering that the previous growth continues till saturation, the time series of KWh and KW are examined, reviewing fuel and plant prices, likely new industries, improved efficiency, demand management, conservation and environmental measures.

(b) Correlation - Synthesising the factor behind demand, example predicting KW for future economic scenarios and using correlation of electricity with population, per capita income, consumer number, type and class, sales of appliances, industrial production etc.

(c) Market surveys - electricity consumption is examined using various credible tariffs for existing and new residential communities, industrial or commercial estates, demand estimated using consumer number, type and class.

(d) Judgement - where the future growth rates are determined based on the judgement of the forecaster without explicitly being governed by trends or projections, though they might have been considered subjectively to arrive at the growth rate by the forecaster.

(e) Multiple opinion - the growth rates are determined by averaging several existing or solicited forecasts by other experts, and

(f) Modeling - where growth rates are obtained through elaborate exercise of quantitative models linking energy consumption to numerous social and economic variables.

Each of the methods mentioned above are only relevant to specific time frames. Though they are tested methods, all of them have certain inherent drawbacks. And one need to be sensitive to the fact that the numerous uncertainties affecting all the variables, cannot be modeled accurately, and hence forecasting can only provide approximate future value and more specifically the direction of movement of demand. According to some economists, to reduce the uncertainty factor and for a realistic forecast model, one needs to take into consideration the world as well as national economic and energy growths before forecasting electricity growth. An interlinking model using elasticities has been discussed by *T.W. Berrie* (1992) which looks at all the macro and micro level factors affecting electricity demand.

According to Berrie, electricity planning is not linear but an interactive exercise. Historically it begins with demand forecasting using semi-exogenous data on cost and price. Then, subsequently it is required to find the least cost way of meeting this demand, costing this and pricing these electricity supplies. This is followed by micro decisions as to whether consumers will pay the long-term prices, whether utility can find its own capital and obtain enough annual revenue etc. Thus the forecasting exercise in this case is assumed to be a sequential/dynamic process.

Poor load forecasts are economically detrimental because of vast associated resource and opportunity cost. Moreover load is a critical component in the short as well as long term economic planning.

3 Major determinants

In the electricity sector, the forecasting is generally carried out on a sectoral basis. The sectors are defined on the basis of the consuming class, which are broadly, domestic sector, commercial sector, agriculture sector and industrial sector. These sectoral demands are in turn influenced by sector specific socio-economic parameters besides, the price of electricity and the price of alternate energy forms.

Broadly, following are the types of demands and their determinants:

1. Residential demand, which is influenced by many socio-economic factors, includes, fuel prices, per capita income, and the available technology. The most important factor being number of households. The demand forecast exercise for this sector necessarily needs to take all these factors into account.

2. Commercial demand, is also influenced by the fuel prices and the available technology. The commercial sector demand model as adopted internationally, projects the amount of commercial floor space and then predicts the fuel choice, efficiency choice, and the use of energy consuming equipment necessary to service this floor space.

3. Industrial demand, in many cases is the largest of the four consuming sectors where, unlike the residential and commercial sectors, the uses of electricity are extremely diverse thus making it difficult to generalize the end uses of energy. The sector is therefore, generally, decomposed into sub-sectors based on the similarities in the nature of electricity consumption in the production process and energy intensities. Thereafter the net value added and energy intensity factors are used for projecting electricity consumption.

4. Agricultural demand primarily depends on the pumpset utilisation, the area cropped, amount of rainfall, irrigated area, the productivity of the land etc. Variations in any of the above conditions have an impact on the electricity consumption by the sector.

In the following sections we will briefly review the existing literature (both national and international) containing the various methods of forecasting the demand for electricity besides an analysis of the impact of the various underlying factors that effect the demand for electricity.

2.4 Literature

Demand forecasting in electricity has been a widely researched topic as it is an exercise, which is sensitive not only to economic but also geographical, environmental and social parameter. Thus in literature extensive reference of both macro as well as micro parameters are available in forecasting model exercise. Depending on the objective/purpose of the forecasting exercise, the time frame/ period of forecast and the level of accuracy essential, a wide range of models can be defined. This section attempts to summarise some of the relevant

models. The forecasting techniques adopted are the select few as already discussed above. Thus the model variation is mainly due to the different sets of explanatory variables taken into consideration for forecasting purpose.

Most of the literature deals with only sectoral forecasts, with focus being primarily on domestic, commercial and industrial electricity demand projection. However some studies also look into forecasting electricity demand in total, attempting to identify the underlying economic and geographic factors. The following section provides a survey of some of the relevant literature in electricity demand forecasting.

There are many studies addressing the issue of forecasting of total electricity demand. However in this chapter, two specific studies have only been addressed, namely the study by *M. Ranjan and V.K. Jain* (1999) and *Roger. R. Betancourt* (1981). The former study looks into the consumption pattern of electrical energy in Delhi during the period 1984-93 and relates it to population and weather sensitive parameters. Linear multiple regression models have been built for different seasons, namely winter, summer, pre-monsoon and post-monsoon seasons. It was found that population and temperature are significant explanatory variables in the model for energy consumption in winter, summer and the post-monsoon seasons. The other meteorological variables are not found to be significant in the models for these seasons with the exception of rainfall, which is significant in the case of the post-monsoon season. In the case of the pre-monsoon season, the explanatory power of the model was found to be very poor (approx. 39%) and sunshine duration and relative humidity were the only variables that were found to be significant. Thus the authors conclude that linear regression models capturing population and weather variation can account for most of the variations in the electric energy consumption in winter, summer and post-monsoon months.

The other study by *Roger. R. Betancourt* has carried out an econometric analysis of electricity demand in the short-run, with an emphasis on the price elasticity of electricity. The study develops specific functional forms, which explain the demand of electricity. The characteristic of these functional forms is that the (uncompensated) price elasticity of demand is allowed to vary with the previous level of the price of electricity and also with the extreme weather conditions (in terms of heating or cooling degrees). Thus these functional forms attempt to capture the behavioral and technical characteristics of the demand

for electricity in the demand function. The study applied these functional forms to time series data for individual utilities. The substantive conclusions of the study were that income and price elasticities under normal conditions are similar for the peak and the average. Thus in areas where cooling degrees are an important component of the rate of growth of peak demand, allowing the price elasticities to vary with weather conditions is a viable alternative to the usual practice of estimating constant price elasticities. Allowing the price elasticity to vary with the level of price of electricity aids in the evaluation of the impact of time-of-day pricing schemes since, though electricity demand may not be sensitive to price under normal conditions, it may become sensitive as the price increases. The study thus concluded that attention must be paid to the actual magnitudes of peak prices in time-of-day pricing schemes.

The other important debate with reference to total electricity demand is its close nexus to economic growth. In the early 70's when world economy was in its growth path and the economies of the world were trying to determine the expansion requirement of its infrastructure sector, the commonly used explanatory variable was economic growth. However slowly as the economies stagnated the predictability factor of economic growth declined. However – there are still studies carried out analyzing the past linkage, one such study is that carried out by *Harridutt Ramcharran (1990)* which specifically examines the relationship between electricity consumption and economic growth in Jamaica during 1970-86, a period of rapid increase in energy prices. The results show that the aggregate demand for electricity is slightly income elastic and that electricity has a significant impact on economic growth. The other observations are that the electricity intensity has increased over time, residential demand is fairly income elastic, commercial demand is price inelastic and the rate of adjustment is slow. These results also suggest that conservation policies could be ineffective, therefore, indigenous sources of electricity are important for Jamaica to be less dependant on imported energy.

The other study on similar lines but for China is that by *Jim Ping Huang (1993)* which studies the relationship between electricity consumption and economic growth during 1950-80. The result show that the income elasticity of electricity consumption is significantly greater than 1, ranging from 2.33 to 2.72, and the electricity-GDP ratio, or electricity intensity, has increased over time with the growth rate of 7.3 % pa during 1950 – 80. These results suggest that the policy makers in China should pay more attention to electricity conservation policies

and structural changes in production to ensure a sustainable growth of both the sector and the economy.

However, in literature most of the studies focus on sectoral demand forecast, addressing any one of the sectors – household or residential sector being the most researched. In this literature survey too, these sector specific studies have been addressed. The residential sector studies have tried to identify different explanatory variables to obtain accurate forecasting model based on various economic theories. The studies at times encompass the entire energy sector and do not specifically restrict itself to electricity sector. However the same models can be easily replicated for the electricity sector alone. For example, the study by *G. Flaig (1990)* uses the household production theory to develop a forecasting model. This theory states that energy is not a consumption good but an input factor to the household production process. Earlier work has demonstrated the empirical relevance of the formulation in a static process using highly aggregated data. This study estimates a dynamic model for electricity demand using 3 groups of households. The study assumes that the utility at each moment depends on two goods one of, which can only be purchased in a market while the other can be either purchased or produced by the household itself using capital and energy. The demand function for capital and energy are derived by maximizing the utility with respect to the budget constraint of the household. This study uses partial least square method and is based on annual data for German households during the period 1964-83. The main findings of the study are that higher prices of market services (laundries, restaurants, theatres, etc.) induce an increase in the rate of household production and hence demand for electricity. On the other hand, higher incomes and lower prices of durables cause the substitution of energy for labour. Moreoever the demand for durables and electricity were found to be price inelastic. A dynamic version of the partial least squares method was also developed which took into account the measurement errors in data and captured the response of electricity consumption to the price and income changes in the long run. However the main problems faced in this exercise were the lack of precise and reliable data on the aggregate stock of electricity consuming durables, user costs of capital, relevant prices of services and permanent income. Further due to complex multipart tariff schedules, only crude indicators of perceived costs of consuming electricity such as published price index of electricity has been used. Thus the model was unable to capture the regional differences and the impact of multipart tariff.

The other study, which also addresses the household energy demand, is that by *C. Sheinbaum, M. Martinez and L. Rodriguez (1996)*. In their study of the residential energy use in Mexico, they note that there is a large potential for growth in electricity demand from this sector due to demographic growth, urbanization, and increasing appliance saturation. The other interesting observation of the study is that the residential sector uses 20% of the final energy demand. The various forces that shape the residential energy use considered in this study are income, energy prices and structural changes in the economy. It is observed that increasing incomes would result in increasing consumption of electricity. Further, an increase in the price of energy coupled with decreasing purchasing power instead of leading to a decline in energy demand, resulted in greater proportion of the household income being spent on energy. The study has also looked into the structural changes in the economy and its linkages to electricity consumption. In the case of Mexico, with increasing migration from rural to urban areas and a decreasing household size, the energy sector has witnessed an increasing demand for electrification of households and hence an increasing demand for electricity. An interesting observation made by the paper is that electricity consumption has increased even though real salaries have decreased, which has been explained as being due to the increasing share of women in the salaried workforce resulting in an increase in the total household income. The study also analyses the various end uses of electricity as well as energy in the residential sector to identify sources of the increasing demand for both. It was observed that there had been a major shift from fuel wood to LPG for the purpose of cooking. It was also found that lighting accounts for 4% of final residential energy use and 40% of the electricity used by households. The average urban household owns 5 bulbs which burn for about 3.5 hours a day approximately. The energy use by other appliances has been estimated by assuming a constant norm for the per unit consumption and studying the penetration level and ownership patterns. The paper concludes by making observations on the technical potential for conservation and DSM, consumer awareness issues, need for an implementation of appliance standards, etc.

The other study on residential sector also addresses energy demand as a whole but with specific reference to the electricity sector wherever possible. The other highlight of this study is its attempt to link the income category (using floor space of accommodation as proxy) to the usage pattern of the household. The study done by *J.C. Lam (1996)* analyses the residential energy use in Hong Kong

by dividing the sector into 5 residential flat classes, A,B,C,D and E in terms of floor area. It was observed that the average houses in class A consumed only 14% of the electricity consumption of an average household in class E. In good approximation, the average annual electricity use was found to be proportional to the floor area. Also it was observed that most residential flats are high-rise wherein communal areas account for 20-30% of the total residential electricity use. In the study, householders were asked about the number of appliances, their power ratings, operating characteristics and patterns of use. In addition portable energy analysers were used to measure electricity use by various appliances. Measurements were made both in summer and winter to account for seasonal variations in use. It was found that the ownership levels of air conditioners was 50% and that they were the most popular intended purchase. The study found that the share of electricity use for air conditioning as a percentage of the household electricity consumption was 36.8% in 1993 and that this was the single largest electricity consuming item. It was found that fluorescent tubes and tungsten filament light bulbs are the two most common electric lamps used. Lighting accounted for 10% of the total household electricity use and many households responded positively to conservation measures, stating that they would install energy saving lamps in the near future. Refrigerators were found to be the second largest energy-using item while televisions, VCRs, washing machines and tumble driers were found to be a small percentage. Other miscellaneous appliances such as fans, irons, audio systems, microwaves, exhaust fans, etc have high ownership levels and their pattern of energy use do not vary much. The study uses the above information to calculate norms for energy use of each appliance. It has been deduced that the increase in energy consumption from 1979 to 1993 was mainly due the increase in air conditioning and that with this growth is slowing down due to saturation, the future forecasts need to alter the growth path accordingly.

Importance of price and also income in determining the household electricity demand has been brought out well in two other international and one domestic studies reviewed, addressing the household sector. *B. W. Ang, T. N. Goh and X. Q. Liu (1992)* found that the residential electricity consumption in Singapore increased at a rate of 8.8% per year between 1972 and 1990 and that the estimates of the long-run income and price elasticities were 1.0 and -0.35 respectively. But besides income and price, statistical analysis shows that the other factor to which the demand of electricity appeared to be sensitive was small changes in climatic variables, particularly the temperature, which is

closely linked to the growing diffusion of electric appliances for environmental controls. Ownership increase of appliances was also observed to be a driving factor, with a large part of the future growth in electricity demand expected to arise from the growing need for air-conditioning, which will lead to increasingly large seasonal variations in electricity use.

The domestic study referred to above was carried out by The *Tata Energy Research Institute* – a report on *Urban Household Energy Survey (May 1988)*, which estimates the energy consumption by end-uses for the five different energy regions in India and assesses the impact of increasing incomes on energy demand. The survey of 972 urban households was based on a simple stratified random sample wherein the urban areas of the country were divided into three categories by density of population. The data collected was coded, processed and analysed to obtain results for each region regarding the seasonal variations in energy consumption, end-uses and fuel-mix across various income categories, and to quantify the percentage of income spent on energy across income categories. The study found that progressively lower shares of income are spent on energy with increases in income. Thus, the lower income categories are most sensitive to any energy price changes. On the whole, energy consumption, both in gross and useful energy terms, was seen to increase with an increase in income. The study further compares the energy consumption by various end-uses across the various income categories. It was found that the southern region had a relatively high level of efficiency in cooking across income classes, while the eastern and central regions had the lowest efficiency. The western region was found to have the highest consumption for water heating, lighting, space cooling while the northern region consumed the highest amount of energy for space heating. The study further examines the income-wise mix of fuels in the different regions.

Besides price, the other factor identified to have a dominant impact on household demand for electricity is 'weather/climate' variables. The *Load Forecasting Department* in its study used the method of weather normalization of sales to adjust for the weather factor. Because of structural differences between customer classes, total sales were grouped into residential and non-residential customers, with the latter further disaggregated. A basic model of sales per residential customer using monthly observations from the period January 1979 to October 1991 was developed for the residential class of customers. The result shows that the model explains 98% of the variation in

monthly consumption. The pattern of electricity use is described by a combination of weather and non-weather variables. The various significant variables and their respective impacts on the sales are degree-days, time and monthly dummy variables, which allow the model's intercept to vary throughout the year. These variables capture the effects of factors such as school vacations and holidays that vary from month to month but are fairly constant for years for a given month. The non-residential sector is much more heterogeneous than the residential, however customers were grouped homogeneously and a similar exercise as household sector was carried out. The study found that actual and weather normalized sales for the test period shows that weather normalized sales is greater than actual sales. The weather-normalized sales are greater than the actual sales by nine-tenths of one percent.

But the most detailed study at a micro level of the household sector was carried out by *The European Community Network's methodology on electricity demand forecasting* for the household sector of the province of Capiz, Philippines. It is an application at a local level, of the methodological approach developed by the European Communities Network on Energy Planning in Developing countries (EC-NEP/DCs). The household sector of Capiz was broken down into 42 homogeneous modules, characterized on the basis of the natural environment, socio-cultural features, economic production modes etc. The explanatory variables considered in the model were number of households, household size, income, urbanization, availability of fuel, appliance ownership etc.

To map future energy choices, scenarios were elaborated describing the reference economic and social system for the forecast year i.e.2003. These scenarios were offered as a range of possible futures that would provide the framework for testing and comparing the consequences of different choices. In the absence of provincial long-term socio-economic scenarios, the Asian Institute of Technology (AIT) team has explored the three following scenarios based on analyses of past and present socio-economic situations, and on possible future changes in provincial energy development. The base case assumes that all past trends continue in the future. The Renewable Energy development Case assumes that the penetration of biogas systems in the rural areas of Capiz would increase, given the favourable provincial endowment. However, this option is assumed to be achieved in a context of high economic growth (5% per annum), high urbanization, i.e. urban population will grow at an

annual rate of 4.2% between 1983-93 and 4.4% between 1993-2003. The third scenario, the Energy Conservation Case is similar to that of scenario 2, except that it includes an option on utilization of improved energy efficiency equipment, such as the Lorena type of stove, etc.

Within the context of these three scenarios, future household energy demand is calculated by first estimating the long-term household population. The breakdown of the household population into zones, location and economic activities is based on trend analysis of the various censuses. The distribution of the household population among the three income groups, i.e. low, medium and high income is based on hypothesis and judgement. The specific energy consumption of each of the end-uses considered in the homogeneous modules is then calculated. It is assumed that in the medium term (1993), the situation will be very similar to the present one. In the long term, changes will depend on the household location, income and economic activity. The estimate of the ownership of appliances is done using a trend analysis and judging the future effects of economic development.

It was found that there is a sharp difference in the future final energy demand of the three scenarios. In scenario 1 (Base Case), final energy demand would grow at an annual rate of 3.3% between 1983-2003. This is significantly higher when compared to that of scenario 2 (Renewable Energy) where final energy demand would decrease at an annual rate of 0.5%, 53% lower than that of scenario 1. If an energy conservation policy (scenario 3) is implemented, the decrease in final energy consumption is more significant, 2.7% per annum between 1983-2003. The end-use pattern will not change dramatically, i.e. cooking will continue to dominate the set of end-uses. However, substantial changes will occur within each end-use depending on the type of scenario. Thus, final energy demand for cooking will grow in scenario 1 but will decrease in scenarios 2 and 3 , whereas for electrical appliances, the final electricity demand will grow at a rate ranging from 10.6% to 11.7%. The demand for electricity would dominate future modern fuel requirement by urban households. In the rural sector, biogas will account for the largest share in the total final energy and the demand for kerosene will be far from negligible (13.6%), but in urban areas where electricity will replace kerosene for lighting, the share of kerosene will amount to only 2.4%. In contrast, the share of LPG will increase from 8.5% in 1983 to 12.2% or 12.7% depending on the scenario.

G. A. Hankinson and J. M. W. Rhys (1983) described an analysis of recent trends in industrial output and electricity consumption carried out at the Electricity Council. The analysis examines the significance of changes in industrial structure and in the intensity of electricity use within major industries using a simple arithmetical procedure. The conclusion reached was that such factors, in those years, had a major influence on the trends in industrial electricity consumption. The importance of those factors explains why simple econometric models which describe industrial electricity sales as a function of total industrial output have proved unsatisfactory for forecasting purposes. This conclusion underlines the need to use a disaggregate approach for electricity.

The most intensive study on forecasting though has been the one carried out by *Northwest Energy Policy,* which did *Project on for Energy Demand Modelling and Forecasting*. The study developed an all fuels (electricity, oil, natural gas and coal) econometric demand-forecasting model for the Pacific Northwest, and for each of the states of Washington, Oregon and Idaho, for the period of 1975 to 2000 - demand forecasts were prepared in five-year intervals. A range of low, moderate and high growth rates of the demand for energy were defined as scenarios and calculations were made for each of the fuels, the states, and summed to the region. The forecasting methodology employed for this study was an econometric one. The aggregate demand estimates for each of the energy sources and for total energy (measured in British thermal Units – BTUs) were obtained by summing the demand estimates across the major consuming sectors: Residential, Commercial, Industrial, Transportation and Irrigation.

There were different models developed for each of the consuming sectors to determine the demand of electricity for each. The residential sector was broken down into two components, namely, saturation related and residual for which separate equations were defined. The explanatory variables included in the two equations were marginal prices of energy, per capita income, appliance prices, saturation ratios in the previous period, prices of energy alternatives, the price of consumer durables, and conservation factors to the extent they can be included. The total residential demand was calculation on the basis of the average usage per household (obtained for a given saturation and intensity level), the residual estimate and the number of households.

In case of the commercial sector again two types of equations: Cost share equations and a total energy demand equation were adopted for forecasting. Price of energy components was taken as an explanatory variable and a one period lag introduced to capture the delayed substitution impact of price change. Total energy demand was considered as a function of employment in the commercial sector, per capita income, heating degree-days, and the average price of all Btu's. The total electricity demand was then derived on the basis of total expenditures (derived by multiplying total demand by total average price) by the commercial sector on energy, the forecast cost share of electricity, and the forecast price of electricity, yielding demand. An inverse relationship was observed to exist between the price of electricity and electricity's share in the total cost of energy.

The model for the industrial sector was basically the same as that described for the commercial sector, except that instead of one homogeneous sector, the industrial sector was divided into 22 sub-sectors identified by the Standard Industrial classification Code. In addition coal as a source of energy was included in the industrial sector.

Demand for electricity for irrigation was taken as a function of the number of irrigated acres of land, the average price of electricity sold for irrigation, the amount of rainfall during irrigation months, and a lagged response to the amount of rainfall.

The ultimate analysis predicted a demand for electricity lower than what had been experienced in the Pacific Northwest in the previous ten years. However this decline was explained by the assumption made with respect to the price of electricity, which was assumed to increase significantly in the forecast period whereas the past decade witnessed a decline. This retardation in demand thus was attributed to not only own price elasticity but also to substitution effect by other fuel.

Thus the methodology used in demand forecasting as available in international literature is varied as discussed above. However domestically, the forecast approved and used for national investment and policy decisions is prepared and documented in the *Electric Power Survey (EPS) by Central Electricity Authority (CEA)*. The EPS uses pre-conceived growth rates on the given historical load data to predict future sectoral demand, where the total demand is

assumed to constitute of sectoral demands. Then applying the load factor the peak demand is predicted. In this case the basic assumption of the growth rate can be questioned. The following are the certain salient features of the projection exercise:

a) The "Partial End Use" method is adopted for projecting the power demands over short and medium time spans.

b) The long-term forecasts for 2006-07 and 2011-12 is worked out by extrapolating the energy requirement (at Power Station Busbars) obtained on the basis of the detailed forecast up to 2001-02.

c) The growth rates have been determined after studying the growth rates anticipated during the period 1993-94 to 2001-02 and keeping in view the enlarging base and liberalised economic policy.

d) The peak loads have been estimated after applying suitable annual load factors on the basis of the anticipated trend up to 2001-02.

e) Further, suitable diversity factors had been applied to work out the regional simultaneous peak load (the all India peak loads given in the 15^{th} Power Survey are sum of regional simultaneous peak loads whereas up to the 14^{th} Power Survey, it was aggregate of state-wise peak loads).

Thus in the short run, for the different sectors specific models are defined to forecast the sectoral electricity demand.

3 Secondary models

3.1 Introduction

In this chapter an attempt has been made to analyse and forecast the quantum of electricity consumption in the state of Gujarat in the short (2002-03), medium (2006-07) and long run (2011-12) on the basis of available secondary data. Demand for electricity comes from various consuming agents/sectors broadly categorised (in the Indian context) under (1) domestic, (2) agriculture, (3) commercial, (4) industry and (5) others. The 'others' category includes railway traction, public lighting and public water works. Purpose and pattern of usage of electricity is different for different consuming sectors and as such a sectoral demand analysis is adopted with the aim of quantifying the relationship between the level and pattern of electricity consumption and economic activity variables such as GDP, population, urbanization etc. in each sector. The contribution of the 'others' category in total consumption of electricity in the state being only 3 percent (as recorded from the past trend), the sectoral demand analysis is carried out for the four other sectors, viz., agriculture, commercial, domestic and industry. The 3% share is assumed to be maintained over the forecast period. Thus to arrive at the total state consumption, the estimated demand of the above four sectors is aggregated and a further 3% added to account for demand by the 'others'. Thereafter, the transmission and distribution loss estimates are added to the total consumption to obtain the final requirement at the bus bar.

3.2 Database for the analysis

The projection exercise addresses each of the sectors separately and thus sector specific variables are identified. Information on the same is collected from various government publications. Specifically, time series data for 18 years - from 1980-81 to 1997-98 for each of the four categories of consumers has been compiled on the following variables: (i) units of electricity consumed by different consumer categories, (ii) net (real) state domestic product by economic activities, (iii) population of Gujarat, (iv) number of pumpsets energised for irrigation purposes in the agricultural sector. The minimum number of observations to be included for a statistically significant result is usually said to

be 30 and the reliability of the estimate improves as the number of observations increases. Thus, the eighteen data points as considered in the present study could be subject to debate. However, for this particular study it may not be relevant to consider data prior to 1980 as the economy in general and the power sector in particular has undergone a considerable amount of structural change. There has been a sizeable shift of the economy towards industrialisation and urbanisation. The power sector too has experienced restructuring and reform to a large extent. Moreover, consumer category wise electricity consumption data as required by our study is not available prior to 1980 as the classification of electricity consumers was not the same as in the present case.

(i) Sectoral/Consumer categorywise consumption

Annual data on units of electricity consumed by different consumer categories for a period of 18 years from 1980-81 to 1997-98 has been compiled from Electric Power Survey (EPS) Committee's Report published by Central Electricity Authority, particularly from the 14th, 15th and 16th EPS. These have been verified with the data provided by GEB. The data provided in the tariff filings by SEC and AEC were also considered for consistency.

(ii) Net State Domestic Product (NSDP)

Data on the state domestic product (both gross and net) by economic activity till 2000-01 of each and every state is being compiled by Central Statistical Organization and published by the Economic and Political Weekly in National Accounts Statistics. The same database is used in the present study in which the contribution to NSDP by different economic activities has been clubbed as depicted below to define sectoral contribution to NSDP. The respective NSDPs are often used as explanatory variable for sectoral consumption.

- Commercial sector (denoted by NSDPS): contribution to net state domestic product by (a) the tertiary sector comprising of namely, (i) trade, hotels and restaurants, (ii) transport, storage and communication, (iii) banking & insurance (iv) real estate, ownership of dwelling, (v) public administration and (vi) other services and contribution from (b) construction and (c) electricity, gas and water supply.

- Industrial sector (denoted by NSDPI): contribution from (a) manufacturing (registered and unregistered) and (b) mining and quarrying.

- Agricultural sector (denoted by NSDPA): contribution from (a) agriculture, (b) forestry and logging and (c) fishing.

However for domestic sector, the NSDP for the state as a whole is assumed to be the income accruing to the sector and has been taken as a proxy for the income in the domestic sector.

(iii) Population

Population of Gujarat is obtained from a Government of India publication titled, Census of India, 1991 which provides population as well as its vital statistics at the state level. The publication also gives state level population projection till 2016 on an yearly basis.

(iv) Pumpset energised

The Directorate of Economics and Statistics, Government of Gujarat, Gandhinagar records annual data on number of pumpsets energised in the agriculture sector in Gujarat. The same is obtained from their publication titled, 'Statistical Abstract Of Gujarat State 2000'.

It may be mentioned here that various other variables such as average tariff realisation, value added in industry, average rainfall, etc. were tried out during the exercise. The models mentioned here were found to be most parsimonious and thus use an optimum number of variables to get the best fit.

3.3 Methodology used for projection

The secondary models developed for sectoral projection of demand for electricity is based on two different approaches. One of them builds up a structural model relating demand to various economic and sector specific factors and the other approach projects the sectoral demand based on intensity of electricity consumption of respective sectors over time. Thus the secondary models developed can be categorised broadly into (i) structural model and (ii) intensity models.

The structural model, as the name suggests, explains sectoral consumption as a function of underlying structural variables that are expected to affect consumption in the respective sectors. This is done by studying the effects of the various driving factors on the dependant variable, in this case, the demand for electricity. The explanatory/independent variables for the various sectors are

different as the purpose of electricity usage in the sectors are different. The various explanatory variables considered and the model built in each of the sectors is discussed in the following section.

Electricity intensity on the other hand measures the quantum of electricity consumption per unit of output or value added in the sector. For the present study sectoral contribution to net state domestic product is taken as a proxy for sectoral output to estimate electricity intensity of each sector. Electricity intensity may be looked upon as an indicator of the efficiency level of appliances. Changes in electricity intensity over a period of time may therefore give a picture of the conservation measures taken by electricity consumers. On the other hand in the case of a rapidly growing economy an increase in intensity may also indicate greater usage of electrical appliances.

Intensity model is developed to see how time has an impact on the electricity intensity, which in turn affect the overall level of electricity consumption in a sector. Once again, the approach has been to fit some sort of time trend to past behaviour. Accordingly, the following section provides regression equations estimated for each of the four sectors.

3.4 Sectoral Models

3.4.1 Domestic/Residential sector

3.4.1.1 Structural model

Electricity consumed by the residential sector is in most cases a final demand, for the purposes of lighting, space conditioning, cooking, water heating, refrigeration and for electrical appliances like washing machine, television, iron etc. Various socio-economic and technological factors such as the level of income, population size, average size of homes, ownership of appliances, and customs and habits of consumers, and efficiency of end-use devices affect the electricity consumption of this sector. The main difficulty faced in analysing electricity demand in the residential sector is the availability of data, especially of the end-uses of electricity. An end-use method, however, has been attempted using primary data collected as a part of this study and is discussed in chapter 5.

However in this chapter with available secondary data, an aggregate analysis is undertaken whereby total electricity demand in the sector is being explained by macro variables such as population growth and per capita income. The

underlying logic is that as the level of income improves, average dwelling space per home tends to increase and so does the demand for lighting, space conditioning and other appliances which results in increases in electricity demand per home. Again, demand for electricity for purposes of electrical appliances like refrigerator, television sets, irons, washing machine, vacuum cleaners etc., depends on average utilisation hours per period of time, and on efficiency of those appliances. The ownership of these appliances is found to increase with an increase in income upto a certain stage before reaching saturation thereby leading to increase in consumption of electricity. Also, the hours of usage per period of time would increase as people demand for comfort with improvement in financial status. Thus, actual demand for electricity is eventually determined by need, subject to the level of income and price of electricity.

The mathematical model considered for estimating demand for electricity in the residential sector is as follows:

$$C_d = PCC \times Pop$$

and,

$$PCC = f(PCY)$$

where, C_d is domestic consumption of electricity
PCC is per capita consumption
PCY is per capita income

In this study per capita net state domestic product data is being used as a proxy for per capita income. The approach for projecting per capita domestic consumption has been to adopt econometric methods whereby per capita domestic consumption is regressed on per capita NSDP using ordinary least squares method. The following log linear equation is considered :

$$\log(PCDC)_t = a + b \times \log(PCNSDP)_t$$

where, PCDC = per capita domestic consumption
PCNSDP = per capita net state domestic product of Gujarat

The constant a and coefficient b in the above equation are the population parameters to be estimated. Here the estimate of b measures the elasticity of per capita electricity demand with respect to per capita net state domestic product, interpreted as the income elasticity of electricity demand. The income elasticity of electricity demand signifies the percentage or relative change in electricity consumption resulting from a given percentage or relative change in consumer's

income, all other influences on demand remaining constant. Thus 'b' is the ratio of the growth rate of per capita electricity demand to the growth rate of PCNSDP over the same period of time.

3.4.1.2 Intensity model

As already detailed earlier, the intensity model attempts to model the time trend of the consumption intensity of the sector. In case of the domestic sector the demand per unit income in the sector is modelled. The following log linear model is considered for estimating electricity intensity in the domestic sector:

$$\log(C_d / NSDP)_t = a + b \times \log(t)$$

where C_d is the domestic consumption for electricity

t is the time/trend variable

The estimated value of b in this case, measures the percentage change in the electricity intensity in the domestic sector for a given percentage change in time. The result shows that over the period 1980 to 1997, electricity intensity in the domestic sector or electricity-NSDP ratio for the sector grew at an annual rate of 0.27 percent. The regression results are given in Annex 3.1. Projection of the sector's aggregate consumption using the structural and intensity models is presented in table 3.3.

3.4.1.3 Projections

(i) NSDP

The compound annual growth rate of NSDP over a period of 21 years from 1980-81 to 2000-01 is being considered for estimating the future values of NSDP. The past trend reveals that the economy has grown at a rate of 5.4 percent over this period of time. However it will be pessimistic to assume that the same growth rate will continue in the future as well. The wave of economic reform is most likely to move the economy to a higher growth path. Thus the future being uncertain, electricity demand is forecasted taking into consideration three possible macroeconomic growth scenarios, viz. business as usual characterised by a continuation of past economic growth, medium growth and high growth. The scenarios are presented in table 3.1 below.

Table 3.1. NSDP scenarios

Scenario	Annual NSDP Growth Rate
Scenario 1: High growth	8.0 %
Scenano 2: Medium growth	6.0 %
Scenario 3: Business as usual	5.4 %

(ii) Population

As has already been stated earlier, a state level population projection exercise is being undertaken by Government of India and the results are presented in the publication titled, 'Census of India, 1991'. In the present study the population figures of Gujarat considered for future years are the ones taken from the above source. Projected per capita domestic consumption is given in table 3.2.

Table 3.2. Domestic sector - Forecast of per capita consumption (MU) and population (million)

Year	Scenano 1	Scenano 2	Scenano 3	Population
	Per capita domestic consumption			(In million)
2002	89.26	90.94	96.77	49.64
2006	115.36	121.99	147.01	52.53
2011	160.40	177.72	250.17	56.06
2012	171.89	192.23	279.15	56.69

(iii) Domestic electricity consumption

Thus based on the above models and adopting the projections made for the explanatory variables as discussed above, the electricity consumption of the domestic sector is obtained for the future years for both the models. The models are further developed under three NSDP growth scenarios as presented in table 3.3.

Table 3.3. Domestic sector - Forecast of consumption (in MU)

Year	Scenano 1		Scenano 2		Scenario 3	
	Structural model	Intensity Model	Structural model	Intensity model	Structural model	Intensity model
2002	4431.19	4365.40	4514.56	4414.60	4804.18	4582.76
2006	6059.42	5627.57	6407.91	5820.00	7721.92	6510.74
2011	8992.30	7666.75	9963.08	8154.20	14025.26	10015.62
2012	9743.69	8148.79	10896.67	8715.59	15823.87	10907.15

The fig 3.1 presented below shows the pattern of increase in domestic demand under the assumption of the business as usual scenario.

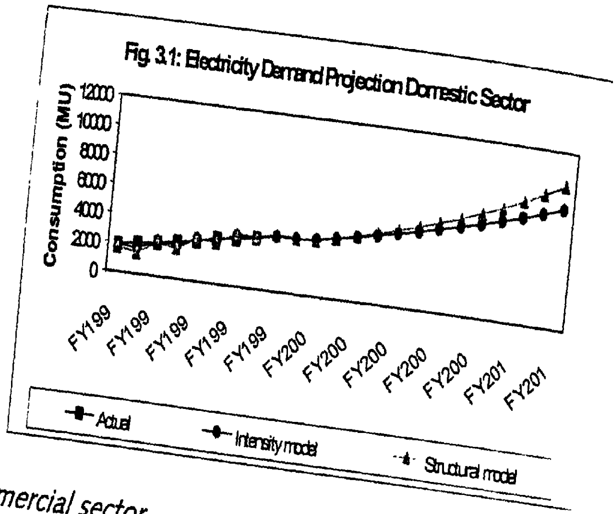


Fig 3.1: Electricity Demand Projection Domestic Sector

3.4.2 Commercial sector

3.4.2.1 Structural model

The commercial sector largely comprises the services sectors, viz. (a) trade, hotels and restaurants, (b) transport, storage and communication, (c) finance, insurance and business services and (d) others. Like in the domestic sector, demand in this sector too is for specific end-uses like lighting, space conditioning and for electrical equipments like computers, printers, scanners, fax machine, photocopier etc. used especially in offices and schools, cooking appliances used in hotels and restaurants, and hospitals and so on. Now, again an end-use analysis which is more appropriate for estimation of electricity demand is not possible due to lack of relevant secondary data and hence an aggregate analysis is undertaken whereby demand for electricity is related to income as in the case of the domestic sector.

The contribution of the services sector to net state domestic sector is considered as aggregate income in this sector. Like in the case of the domestic sector, for this sector too an econometric model is used as an analytical tool to forecast electricity demand of the commercial sector. The following regression equation is fitted and the parameters are estimated using ordinary least square method.

$$\log(C_c)_t = a + b \times \log(NSDPS)_t$$

where, C_c = consumption of electricity by commercial sector

NSDPS = net domestic product for services sector

Here again the estimate of 'b' will give the elasticity of electricity demand of the commercial sector to income growth in the sector i.e. the income elasticity of the

demand in the sector. Thus we obtain the ratio of the growth rate of electricity demand to the growth rate of NSDPS over the same period of time from the above equation as 1.269 as detailed in Annex 3.2.

3.4.2.2 Intensity model

The intensity model for the commercial sector too establishes a relationship between the consumption per unit income for the sector and time. The term 'consumption per unit income' otherwise referred to as electricity intensity of the sector is thus modelled over time. The log-linear model thus considered is represented below.

$$\log(C_c / NSDPS)_t = a + b \times \log(t)$$

where C_c is the commercial consumption for electricity

t is the time/trend variable

The ordinary least squares estimate of 'b' obtained is 0.135 implying that electricity intensity in the sector has increased over time at a rate of 0.13 percent. The growth rate thus established, the future consumption of electricity in the sector is obtained through varying simply the time period under consideration. The regression results are given in Annex 3.2 and projected consumption demand for electricity of the sector using the structural and intensity models is given in Table 3.5.

3.4.2.3 Projections

(i) NSDPS

To project NSDPS, a method based on the concept of elasticity is used. Herein, the growth rate of NSDPS is considered to be proportional to the compound annual growth rate of overall NSDP. Thus based on this condition a log linear relationship is established between the two variables as illustrated below:

$$\log(NSDPS)_t = a + b \times \log(NSDP)_t$$

The estimate of 'b' in the above equation gives the elasticity of NSDPS w.r.t NSDP. Thus for a given growth rate of NSDP (g_{NSDP}), the elasticity factor could be applied to obtain the corresponding growth rate of NSDPS (g_{NSDPS}).

$$g_{NSDPS} = b \times g_{NSDP}$$

From the estimated regression equation the elasticity of NSDPS w.r.t. NSDP is obtained as 1.18 , which implies that if NSDP increases by 1 percent, NSDPS will increase by 1.18 percent. Following the above methodology the three growth

rates of NSDPS obtained corresponding to the three growth scenarios of NSDP as mentioned earlier are provided in table 3.4 below. Based on these growth rates, the future NSDPS series is forecasted under three scenarios detailed in Annex 3.5. However the future series obtained by applying the above growth rate is thereafter moderated to add up to the forecasted NSDP totals for each year to maintain consistency.

Table 3.4. NSDPS scenarios

Scenarios Annual Growth Rate Of NSDP	Annual Growth Rate Of NSDPS
High Growth (8%)	9.43%
Medium Growth (6%)	7.07%
Business as usual (5.4%)	6.37%

(ii) Commercial electricity consumption

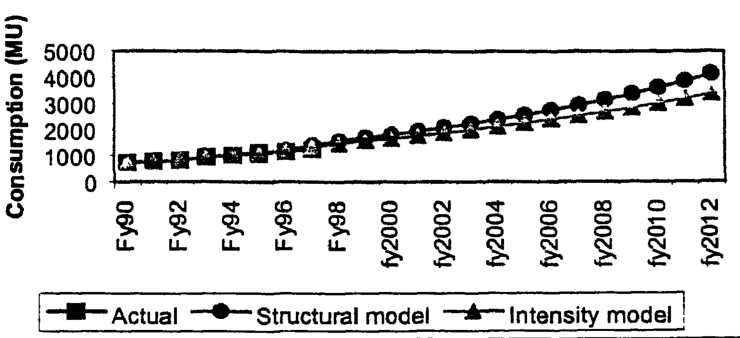
The commercial electricity consumption is thus obtained for both structural and intensity models under three sectoral domestic product growth scenarios respectively. The projections are obtained on applying the projections of explanatory variables (as detailed above) on the respective models. The consumption numbers thus obtained is provided in the table 3.5.

Table 3.5. Commercial sector: forecast of consumption (in MU)

Year	Scenario 1		Scenario 2		Scenario 3	
	Structural model	Intensity Model	Structural model	Intensity model	Structural model	Intensity model
2002	4431.19	4365.40	4514.56	4414.60	4804.18	4582.76
2006	6059.42	5627.57	6407.91	5820.00	7721.92	6510.74
2011	8992.30	7666.75	9963.08	8154.20	14025.26	10015.62
2012	9743.69	8148.79	10896.67	8715.59	15823.87	10907.15

The fig. 3.2 presented below shows the pattern of increase in commercial demand under the assumption of the business as usual scenario.

Fig.3.2: Electricity Demand Projection Commercial Sector



3.4.3 *Industrial sector*

3.4.3.1 Structural model

The industrial sector is generally the most energy-intensive sector of the economy. Electricity, as any other form of energy is consumed by industry as an intermediate product to produce other commodities. Though some electricity consumed by the sector is not directly related to production activities, like lighting and space conditioning, these indirect uses of electricity are negligible when compared to consumption as an input in the production process. Changes in electricity consumption of the industrial sector can thus be explained by the changes in the two determinants: level of industrial output and energy intensity, the latter being energy consumption per unit of value added or value of output. But since the industrial sector as a whole is basically an aggregate of individual production units which produce a number of heterogeneous products, it is difficult to make an accurate forecast at an aggregated level, without considering the disaggregation. On the other hand, the disaggregated industrial output is not possible to model as various technological phenomena are associated with it, which in turn is not possible to predict due to lack of sufficient data. Thus considering industrial GDP as a proxy for industrial output, the ordinary least squares technique is applied to estimate the following regression equation:

$$\log(C_i)_t = a + b \times \log(NSDPI)_{t-1}$$

where C_i = consumption of electricity by industrial sector

NSDPI = net state domestic product for industrial sector

It is important to note that the equation uses lagged NSDPI as an explanatory variable. The underlying assumption here is that unlike the domestic and

commercial sectors, there would be a lag in the response of the consumer to variations in income. This is because any increase/ decrease in income would translate to a rise/fall in demand only due to additional investment/ dis-investment. The latter process however cannot be an instant phenomenon as any purchase of new machinery for expansion or divestment of capital would require considerable planning.

3.4.3.2 Intensity model

The industrial intensity model is also similar to that of the commercial model. The electricity consumption intensity i.e. consumption per unit income from the sector is modelled over time. He net state domestic product of the sector, NSDPI is taken as the proxy for income. The following log linear model is considered for estimating intensity of electricity consumption in the industrial sector.

$$\log(C_i / NSDPI)_t = a + b \times (t)$$

where C_i is the industrial consumption for electricity
t is the time/trend variable

Here the estimate of the slope coefficient 'b' measures the relative or percentage change in electricity intensity in the industrial sector for a given absolute change in time (t). Multiplying the estimated value of 'b' by 100, we get the percentage change of intensity or more specifically in this case the rate of change in electricity-NSDPI ratio over time. The result shows that electricity intensity in the industrial sector has declined at a rate of 2.9 percent over a period of 18 years from 1980-1997. As the economy has moved towards more industrialisation during this period the result indicates an efficiency improvement in the sector. The regression results are given in annex 3.3 and estimated consumption using the structural and intensity models is given in Table3.7.

3.4.3.3 Projections

(i) NSDPI

The NSDPI is projected following the same methodology as in case of NSDPS and then the projected value of the previous year's NSDPI is taken as one-period lagged NSDP for the forecast year. Thus the set of equations considered for projection purpose are as follows:

$$\log(NSDPI)_t = a + b \times \log(NSDP)_t$$

and

$$g_{NSDPI} = b \times g_{NSDP}$$

The elasticity of NSDPI w.r.t. NSDP i.e. the parameter 'b' in the above equation set is obtained as 1.33. Applying the same on the NSDP growth rate, the growth rate of NSDPS is obtained as 6.37 per cent vis-à-vis 5.4 per cent (business as usual) growth rate of NSDP. Similarly the growth rates scenarios of NSDPI is projected vis-à-vis the NSDP growth rates for the other two scenarios as presented in table 3.6 below. The growth rates thus obtained are used to forecast the future NSDPI for the economy as provided in Annex 3.5. Here too the forecast is moderated and adjusted to the NSDP forecast for each year.

Table 3.6. NSDPI scenarios

Scenarios Annual Growth Rate Of NSDP	Annual Growth Rate Of NSDPI
High Growth (8%)	10.66%
Medium Growth (6%)	8.00%
Business as usual (5.4%)	7.21%

(ii) Industrial electricity consumption

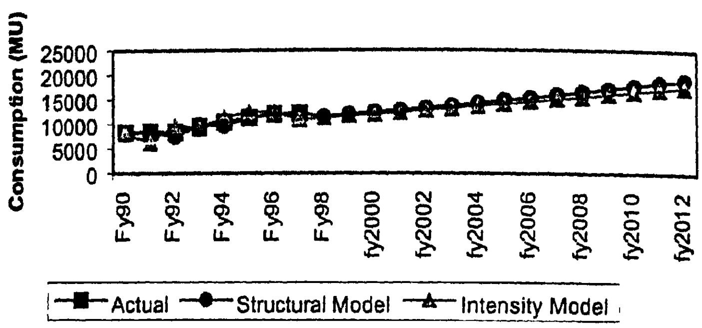
As in the domestic and commercial sector, the industrial sector electricity consumption forecast is also based on the two models, namely structural and intensity. These models are further developed under three NSDPI growth scenarios as provided in table 3.7.

Table 3.7. Industry sector - forecast of consumption (in MU)

Year	Scenario 1		Scenario 2		Scenario 3	
	Structural model	Intensity model	Structural model	Intensity model	Structural model	Intensity model
2002	13215.19	12719.95	13267.46	12890.36	13442.88	13473.41
2006	15325.24	14521.95	15626.40	15105.12	16668.64	17211.77
2011	18393.11	17062.10	19111.54	18319.28	21696.08	23178.39
2012	19070.61	17611.84	19889.20	19028.07	22856.97	24576.38

The fig. 3.3 presented below shows the pattern of increase in industry demand under the assumption of the business as usual scenario.

Fig. 3.3: Electricity Demand Projection
Industry Sector



3.4.4 *Agricultural sector*

3.4.4.1 Structural model

The use of electricity in agriculture sector is mainly for the purpose of irrigation. Agricultural lands are irrigated either by ground water, or from reservoirs, or are rain fed. Irrigation from reservoirs or ground water requires energy for pumping, which can either be done by manpower or by electric motors or diesel generators. Our interest pertaining to the present study lies in estimating the requirement of electricity in particular for irrigation purpose. Annual requirement of electricity is likely to depend on gross irrigated area, number of electric motors used for pumping as well as efficiency of the pumpsets and pattern of rainfall. Now, rainfall and its pattern are supposed to affect irrigation demand for electricity very significantly, but they remain a random factor. The fit of the model with gross irrigated area as an explanatory variable is unexpectedly not good perhaps because of problems in the data. The other reason for the poor fit of the model with gross irrigated area could be due to the presence of a very active water market. Thus, certain big farmers own large pumpsets, which they use not only to irrigate their own land but also to sell water to other small farmers to irrigate their land. This may result in a lack of correlation between the electricity consumption in this sector and the gross irrigated area.

Thus we have established a relationship between agricultural demand for electricity and number of pumpsets energised in the state and the model serves well in terms of goodness of fit tests. The following econometric model is used

for estimating agricultural demand for electricity using ordinary least squares method:

$$\log(C_a)_t = a + b \times \log(PE)_t$$

where C_a = consumption of electricity by the agricultural sector
PE = number of pumpsets energised

In the above stated equation, a and b are the population parameters to be estimated. The estimate of 'b' gives the elasticity of agricultural consumption with respect to pumpsets energised. The future consumption of electricity is thus obtained from the above relationship by forecasting the 'PE' for the future years.

3.4.4.2 Intensity Model

In the projection of agriculture consumption on the basis of intensity model, once again the consumption per unit income is modelled over time. It is assumed that the time factor best explains the electricity intensity with respect to NSDPA for the sector. The following linear trend model is estimated to see how electricity intensive the agriculture sector is:

$$(C_a / NSDPA)_t = a + b \times (t)$$

where Ca is the agriculture consumption of electricity
t is the time/trend variable

The slope coefficient 'b' measures the absolute change in electricity intensity for a given absolute change in the trend or time variable 't'. The result gives that over the period 1980 to 1997 on average the electricity intensity in the sector increased at the absolute rate of about 0.017 MU. The regression results are given in Annex 3.4 and projected consumption using the structural and intensity models is given in Table 3.9.

3.4.4.3 Projections

(i) Pumpsets Energised (PE)

The pumpset energised data on yearly basis is available for the past years. However for projecting the number of pumpsets for future years, it cannot be assumed that the increases in number would continue at the same pace as the past. The growth in pumpsets energised/ ownership is restricted by the fixed upper bound on area irrigated, given that area cropped and irrigated is fixed by nature. Thus, a reasonable assumption is that a saturation level will be reached when no more increases in pumpsets would be due to an increase in irrigated

area. Any increase in pumping requirement would be due to depletion of water table or decrease in rainfall, which would be very marginal. With this view a logistic curve is fitted on the basis of past 20 years data from 1980 to 1999. i.e.

$$PE = a + b \times \log(t)$$

The analysis gives that till 2013 number of pumpsets energised will grow at a uniform rate of 1 percent beyond which it will reach the level of saturation. The forecast values of PE is provided in table 3.9.

(ii) NSDPA

The NSDPA projection is based on the projection made for the total NSDP as in the case of NSDPI and NSDPS. Thus the set of equations considered for projection purpose are also similar and are as follows:

$$\log(NSDPA)_t = a + b \times \log(NSDP)_t$$

and

$$g_{NSDPA} = b \times g_{NSDP}$$

The elasticity of NSDPA w.r.t. NSDP is obtained as 0.38, which is the value of the parameter 'b' in the above equation set. Applying the same on the NSDP growth rates, the growth rate of NSDPA is obtained for the three growth scenarios as presented in table 3.8 below. The growth rates thus obtained are used to forecast the future NSDPA for the economy as provided in Annex 3.5. Here too the forecast is moderated and adjusted to the NSDP forecast for each year.

Table 3.8. NSDPA scenarios

Scenarios Annual Growth Rate Of NSDP	Annual Growth Rate Of NSDPI
High growth (8%)	3.03%
Medium growth (6%)	2.28%
Business as usual (5.4%)	2.05%

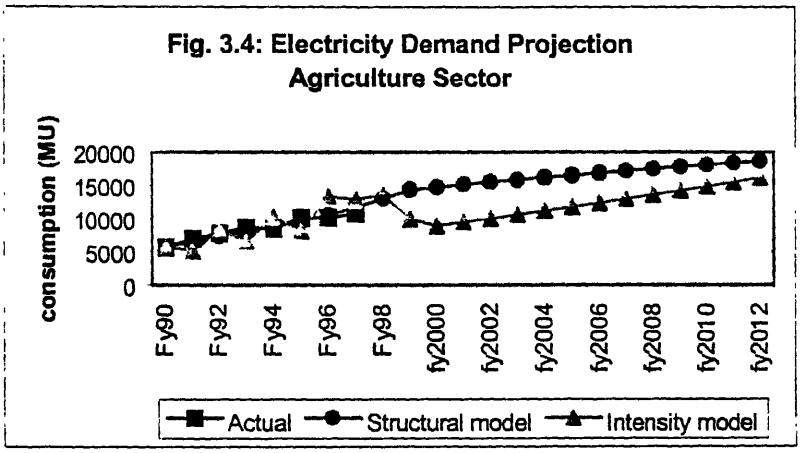
(iii) Agriculture consumption of electricity

The above projections of explanatory variables are applied to the structural and intensity models developed to obtain the forecast for agriculture electricity consumption. The forecast for intensity model in this case is under three NSDPA growth scenarios, while the structural model has only one scenario as it is related to pumpsets energised, which has only one forecast scenario. The details of both the PE forecast and the electricity consumption forecast is presented in the table 3.9.

Table3.9 : Agriculture Sector: Forecast of Consumption (in MU) and Pumpsets Energised

Year			Scenario 1	Scenario 2	Scenario 3
	Pumpsets Energised	Structural model	Intensity model	Intensity model	Intensity model
2002	691108.6	15491.16	10028.54	10059.05	10162.82
2006	715317.3	16869.31	12360.67	12466.89	12829.05
2011	740968.9	18406.63	15522.41	15750.67	16531.84
2012	745614.8	18693.64	16187.31	16443.66	17321.72

The fig. 3.4 presented below shows the pattern of increase in agriculture demand under the assumption of the business as usual scenario.



Microsoft Excel software is used for compiling the data. For running the regressions (both structural models and intensity models) a very sophisticated statistical and econometric software called Eviews is used.

Annex 3.1

Domestic sector

Structural model

Dependent variable	Explanatory variable	Coefficients	t-Statistics	Probability of Type I error
log(PCDC)	Constant	- 9.385	- 5.828	0.000
	log(PCNSDP)	1.663	8.127	0.000

R - Squared	Adjusted R - Squared
0.805	0.793

	Serial Correlation LM Test	ARCH Test
F - Statistic	0.503 (at lag order 7)	0.537 (at lag order 6)
Prob. of Type I Error	0.811	0.764

Intensity model

Dependent variable	Explanatory variable	Coefficients	t - Statistics	Probability of Type I error
log(DC/NSDP)	Constant	- 4.713	-69.578	0
	Log(Time)	0.270	8.639	0

R - Squared	Adjusted R - Squared
0.8235	0.8124

	Serial Correlation LM Test	ARCH Test
F - Statistic	0.191 (at lag order 2)	0.545 (at lag order 6)
Prob. of Type I Error	0.828	0.76

From the structural model results it is evident that real per capita income has quite a considerable influence on per capita domestic consumption. The degree of correlation between them is 0.8. The income elasticity of demand is greater than unity being equal to 1.66, implying that a 1 percent increase in per capita income will lead to an increase in per capita consumption by 1.66 percent. However the negative value of the intercept indicates that per capita consumption will grow at a decreasing rate. Several reasons may be put forward

among which improvement of appliance efficiency and diminishing population growth rate are reasonable.

The intensity model reveals that intensity of electricity consumption is highly dependent on time as indicated by the high degree of correlation coefficient of 0.8.

For both the models, the probability of type 1 error corresponding to the t-statistic is zero implying that in both cases the slope coefficients (coefficient of the independent variable) are significantly non-zero and assume the values as indicated with 100 percent confidence.

In the intensity model too the intercept is negative. Thus the two models appear to be quite consistent and can therefore be used for predicting consumption of electricity in this sector.

The Breusch-Godfrey Lagrange Multiplier test for serial correlation gives that there is a 81 percent probability of no autocorrelation in the residuals of the structural model upto lag order 7. From the autoregressive conditional heteroscedasticity (ARCH) test it is evident that for the structural model there is a 76.4 percent probability of the residuals upto lag order 6 to be homoscedastic.

Similar explanation holds for the intensity model too.

Annex 3.2

Commercial sector

Structural model

Dependent variable	Explanatory variable	Coefficients	t-Statistics	Probability of Type I Error
log(CC)	Constant	-7.115	- 12.842	0.000
	log(NSDPS)	1.269	24.487	0.000

R - Squared	Adjusted R - Squared
0.980	0.979

	Serial Correlation LM Test	ARCH Test
F - Statistic	0.382 (at lag order 6)	0.384 (at lag order 6)
Prob. of Type I Error	0.874	0.862

Intensity model

Dependent variable	Explanatory variable	Coefficients	t - Statistics	Probability of Type I error
log(CC/NSDPS)	Constant	-4.509	-225.854	0.000
	Log(Time)	0.135	14.030	0.000

R - Squared	Adjusted R - Squared
0.843	0.833

	Serial Correlation LM Test	ARCH Test
F - Statistic	0.038 (at lag order 1)	0.651 (at lag order 7)
Prob. of Type I Error	0.832	0.713

The structural model shows that there is a high degree of correlation between income and consumption of electricity in this sector. The GDP elasticity of electricity consumption in the sector is about 1.3 indicating that electricity consumption is income elastic. Probability of Type 1 error corresponding to the t-statistic is zero indicating that the true value of the slope coefficient is 1.269 with 100 percent confidence.

The intensity model reveals that intensity of electricity consumption with respect to income follows a rising trend with time, the correlation coefficient being as high as 0.8.

Probability of Type 1 error corresponding to the t-statistic is zero for this model indicating that the true value of the slope coefficient is significantly equal to 0.135 with 100 percent confidence.

For both the models, the residual tests show that there is a quite high probability of the residuals to be non-autocorrelated and homoscedastic.

Both the models give negative intercepts indicating that rate of growth in demand for electricity in this sector will fall with sectoral income and time.

Annex 3.3

Industrial sector

Structural model

Dependent variable	Explanatory variable	Coefficients	t-Statistics	Probability of Type I error
log(IC)	Constant	2.924	9.125	0.000
	log(NSDPI(-1))	0.591	18.896	0.000

R - Squared	Adjusted R - Squared
0.960	0.957

	Serial Correlation LM Test	ARCH Test
F - Statistic	0.822 (at lag order 11)	0.382 (at lag order 5)
Prob. of Type I Error	0.642	0.845

Intensity model

Dependent variable	Explanatory variable	Coefficients	t - Statistics	Probability of Type I error
log(IC/NSDPI)	Constant	-1.044	-19.972	0.000
	Time	-0.029	-6.071	0.000

R - Squared	Adjusted R - Squared
0.697	0.678

	Serial Correlation LM Test	ARCH Test
F - Statistic	0.730 (at lag order 7)	0.130 (at lag order 2)
Prob. of Type I Error	0.653	0.879

The value of the coefficient of determination, R-squared is quite high 0.96, indicating a good fit of the model and thereby a high dependence of industrial consumption on one period lagged output/income. Unlike domestic and commercial sectors, consumption of electricity in this sector is income inelastic, the coefficient being equal to 0.6. The fit of the intensity model is not very satisfactory leading to the fact that time has no influence on the variation in intensity of electricity consumption in this sector.

Annex 3.4

Agricultural sector

Structural model

Dependent variable	Explanatory variable	Coefficients	t-Statistics	Probability of Type I error
log(AC)	Constant	-23.636	- 19.050	0.000
	log(PE)	2.475	25.727	0.000

R - Squared	Adjusted R - Squared
0.976	0.975

	Serial Correlation LM Test	ARCH Test
F - Statistic	0.769 (at lag order 8)	0.509 9at lag order 4)
Prob. of Type I Error	0.640	0.731

Intensity model

Dependent variable	Explanatory variable	Coefficients	t - Statistics	Probability of Type I Error
AC/NSDPA	Constant	0.010	0.354	0.728
	Time	0.017	6.192	0.000

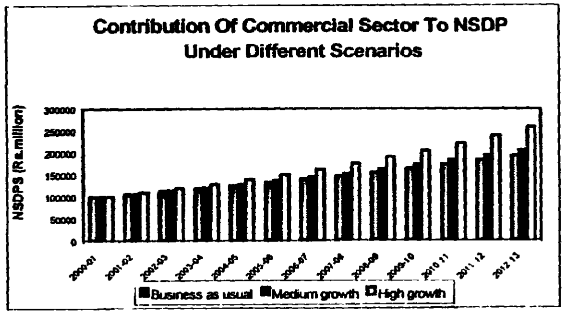
R - Squared	Adjusted R - Squared
0.705	0.688

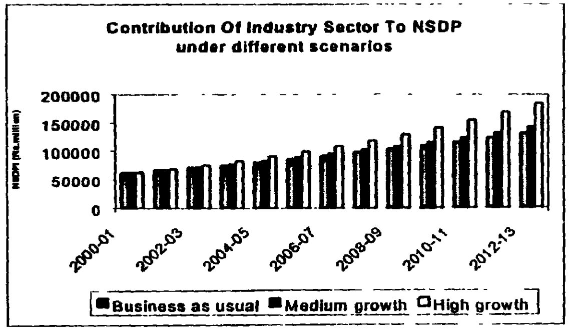
	Serial Correlation LM Test	ARCH Test
F - Statistic	0.390 (at lag order 6)	0.311 (at lag order 4)
Prob. of Type I Error	0.869	0.0.863

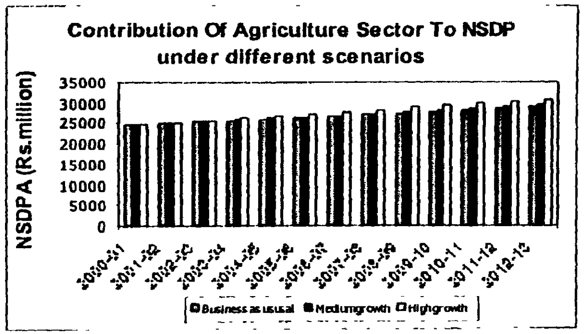
An excellent 97 percent fit is obtained from the structural model. The elasticity of electricity consumption with respect to pumpsets is greater than unity as desired. The intensity model however does not give a good fit. Moreover the probability of Type 1 error corresponding to the t-statistic for the intercept is 0.728 implying that the estimated value of the intercept is 0.010 with a confidence of only 27 percent.

Forecast of NSDP (million) at Factor Cost by Economic Activity at Constant (1980-81) Prices

Year	Scenario 1 : NSDP Growth Rate 5.4% (Business as usual)				Scenario 2 : NSDP Growth Rate 6%				Scenario 3 : NSDP Growth Rate 8%			
	NSDPA	NSDPI	NSDPS	NSDP	NSDPA	NSDPI	NSDPS	NSDP	NSDPA	NSDPI	NSDPS	NSDP
2002	25411.93	70878.38	112283.57	208573.88	25489.21	71827.95	113607.40	210924.55	25752.16	75076.82	118130.08	218959.06
2003	25756.72	75468.63	118627.54	219852.90	25872.41	76984.72	120722.90	223580.03	26266.29	82243.00	127966.49	236475.78
2006	26785.11	90984.83	139713.31	257483.24	27015.27	94638.55	144633.57	266287.39	27800.05	107837.47	162253.86	297891.38
2007	27125.97	96796.74	147484.41	271407.12	27394.04	101331.72	153538.87	282264.63	28308.66	117937.35	175476.68	321722.69
2011	28480.39	123771.58	182798.53	335050.50	28899.22	132891.46	194561.92	356352.60	30332.49	168140.36	239227.32	437700.17
2012	28816.89	131559.45	192792.62	353168.97	29273.25	142138.71	206321.79	377733.75	30836.39	183584.25	258295.54	472716.19







4 Primary data analysis

4.1 Introduction

Primary data are those which are collected for a specific purpose directly from the field of inquiry and hence are original in nature. For collection of primary data, the most important requirement is to construct a comprehensive questionnaire incorporating a sequence of questions relevant to the information required for the study under consideration. For the present study too, four different questionnaires were framed up for surveying four different consumer categories, viz. domestic residential, commercial, industrial and agricultural. Since the aim of this study is to analyze the demand for electricity, the target of the primary survey has been to obtain information on the usage pattern of different electrical appliances used by the different consumers. So a common part of every questionnaire comprises questions related to the number of appliances possessed by a consumer, their capacities, daily hours of usage, number of months of usage, specific time of usage etc. Apart from these, other questions included in the questionnaires are sector-specific. The success of the survey in extracting the required data for this study from the respondents lies in the fact that the questionnaires have been made as simple and as clear as possible.

4.2 Why primary data analysis?

Data are basically required to test the validity of a hypothesized model or simply for numerical analysis of a structural (mathematical) model and thereby to obtain results of interest. If the analysis of the model is based on secondary data, the model gets restricted subject to the available data, while in case of primary data analysis, there is no such restriction as the data collected is pertinent to the requirement of the model (constructed prior to the collection) and therefore models based on primary data are capable of yielding more desirable and reasonable results than models based on secondary data. Further, the primary survey gives the forecaster a qualitative feel of the field of study, which is very important while making projections in the long term. Without this factor, the exercise of forecasting may become an academic exercise which may be far from reality. Thus, secondary data analysis should always be supplemented by primary data analysis, if feasible. As an instance, in case of the present study,

with secondary data it is only possible to build up models whereby consumption of electricity can be related to certain economic factors, viz, GDP, population etc as information from secondary source is available only on these variables. However, aim of this study is not merely to relate consumption to macro economic variables but also to do a micro level analysis, in the sense, to split up consumption into a number of components considering disaggregation at various levels and then aggregating them. The ultimate disaggregation may be at the level of end-uses of electricity. To estimate consumption at the end-use level, information on the usage pattern of various electrical appliances by the different consumer categories, is required as also information on the driving factors of end-use demand. Such specific information can be obtained only through a sample survey of consumers as these information are generally not collected and compiled by Govt., or private agencies. Thus the importance of primary data analysis lies in the fact that it leads to important observations and norms which may be appropriately used as analytical tools for forecasting. For example, in case of agricultural sector, as per availability of secondary data, agricultural consumption can be related merely to the number of pumpsets energised in the state or agricultural GDP. On the other hand, using the primary data we can obtain norms regarding the capacity of pumpset pertinent to the depth of water prevailing in a particular region, hours of irrigation for a specific crop type, number of times a particular crop is irrigated, and so on and such norms can be effectively used in developing models for estimating consumption of electricity.

4.3 Data analysis

4.3.1 Overview of the state of Gujarat:

On an overview of the state of Gujarat, one observes that in terms of most economic indicators, Gujarat is one of the most developed states in the country. Some of these economic indicators are given in table 4.1 below

Table 4.1 : Selected Economic Indicators.

Indicator	Gujarat	India
Literate population in 1991 (%)	61.3	52.2
Relative Infrastructure development Index (1992-93)	125	100
Per capita power consumption in 1994 (kWh)	520	270
%age of villages electrified (31 March 1997)	99.9	84.9
Share of manufacturing in NSDP (%) 1988-89	34.31	26.09
Share of services in NSDP (%) 1988-89	36.78	39.52

Source: Socio-Economic Review Gujarat State, 1998-99

Basic Statistics Relating to States of India: CMIE, September 1994

As shown in table 4.1, the percentage of literate population in the state is 61.3% and ranks ninth amongst the states of India. Further, as on 31st March 1998, 17996 out of the 18028 villages in the state have been electrified. The remaining 32 villages are not feasible for electrification. Thus all the feasible villages in the state have been electrified. The relative infrastructure development index of the state for 1992-93 also shows that the infrastructure in the state is better than the all –India average. The share of manufacturing in the net state domestic product in Gujarat was higher than that for India in 1988-89 while the share of services in the NSDP in the same year was lower than that for India. However, in the recent past, Gujarat has experienced a structural shift in the economy with the share of the primary sector going down to 19.42% of the NSDP during 1997-98. The share of the secondary and tertiary sectors has gone up to 41.91% and 38.66% of the NSDP in the same year.

With the rapid growth in the industrial and services sector, the demand for electricity in the individual sectors has increased. On the other hand, due to a liberal captive power policy of the Government of Gujarat and the relatively easy access of oil and natural gas, Gujarat has witnessed a mushrooming of captive power plants.

4.3.2 Agriculture

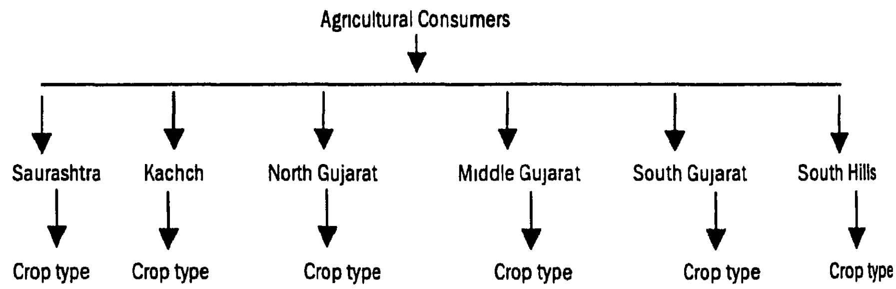
4.3.2.1 Introduction

Agriculture sector is the largest consumer of the electricity sector with its consumption being estimated at 36 per cent of total consumption of the state. However, agriculture contributes only 20 per cent to the state economy while employing 50 per cent of the employment in the state.

So far as agriculture is concerned, Gujarat has several constraints such as limited and poor irrigation facilities, more number of small and marginal farmers, poor economic and social status of farmers, frequent scarcity conditions due to over reliance on monsoon and large area under arid, semi arid and saline condition in some parts of the State. However, the State had recorded a 5 per cent compound Annual Growth Rate (CARG) in food grain production, 14 per cent CARG in oilseeds production and 18 per cent CARG in cotton production from 1991-92 to 1997-98.

4.3.2.2 Sampling details

The state of Gujarat is divided into eight agro-climatic sub-zones. These have been used with slight modification for the purpose of stratification of the sample (as in flow chart below). Further, the various crops grown in the state may be classified under three heads (Table 4.2) - highly water intensive, medium water intensive and dry/rain-fed crops. The highly water intensive category comprises wheat, rice and sugarcane. The medium water intensive crops are maize, mustard, groundnut, sesame and rapeseed. The dry/rainfed crops are bajra, jowar, gram and other pulses.



The following table gives the classification of the various districts into agro-climatic sub-zones.

Table 4.2: Classification of districts into agro-climatic zones and classification of crops therein

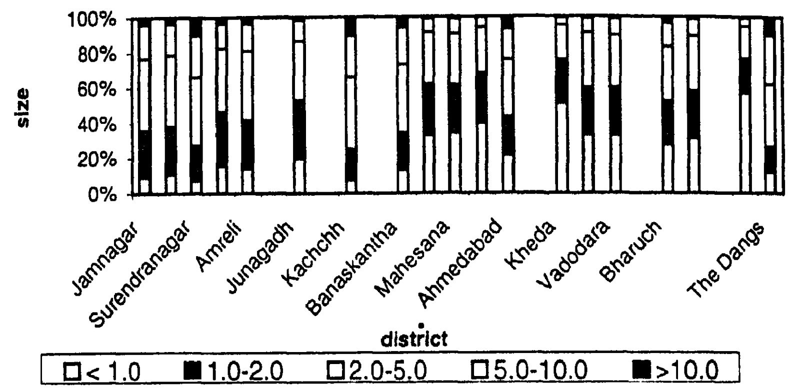
S.No	District	Highly Irrigated		Partly Irrigated		Dry/ Rainfed		TOTAL	Gross Cropped Area	Percentage of area irrigated to gross cropped area	Connected load
		Total (ha)	%age	Total (ha)	%age	Total (ha)	%age	Ha	Ha		MW
1	Jamnagar	43	8%	420	74%	108	19%	571	7175	21.10%	114
2	Rajkot	97	15%	452	71%	92	14%	641	8891	31.55%	256
3	Surendranagar	25	11%	67	28%	145	61%	237	6902	18.91%	270
4	Bhavnagar	18	4%	248	52%	214	45%	480	6661	23.12%	240
5	Amreli	40	8%	345	73%	86	18%	471	5566	21.58%	225
6	Junagadh	67	12%	409	74%	74	13%	550	6642	24.95%	419
7	Kachchh	12	3%	113	32%	224	64%	349	7018	19.49%	233
8	Banaskantha	51	7%	188	26%	482	67%	721	11125	37.59%	735
9	Sabarkantha	97	24%	146	36%	158	39%	401	5335	40.15%	694
10	Mahesana	105	20%	148	28%	285	53%	538	9366	53.12%	695
11	Gandhinagar	17	43%	7	18%	16	40%	40	690	72.61%	226
12	Ahmedabad	223	63%	15	4%	114	32%	352	6135	31.98%	
13	Kheda	240	52%	43	9%	180	39%	463	6498	60.68%	189
14	Panchmahal	177	34%	208	40%	137	26%	522	5883	22.42%	65
15	Vadodara	80	26%	53	17%	177	57%	310	5692	33.87%	347
16	Bharuch	61	23%	15	6%	191	72%	267	4175	17.72%	105
17	Surat	224	59%	27	7%	130	34%	381	4766	46.24%	135
18	Valsad	150	83%	1	1%	29	16%	180	3362	37.45%	73
19	The Dangs	9	36%	2	8%	14	56%	25	569	0.53%	

The total sample size in this category, while ensuring statistical significance of the sample in each of the substrata would be 720. This sample would be randomized over the size of the land holdings to capture the heterogeneity in the consumption of large farmers and small farmers.

On the basis of the available data on land holding from the Statistical Abstract of Gujarat (Figure 4.1) and the details on gross cropped area for different crop-types at a district level, a detailed work plan was charted out. The 720 sample points were allocated amongst the high connected load districts in each agro-climatic zones in proportion to their connected load as far as possible. However since the statistical significance factor had to be taken into consideration, for the district of Valsad the sample considered is 30 that exceeds the calculation, which stands at 16. Thus minor deviations had to be made from the calculated values

for the other districts keeping the total at 720. Thereafter the allocated sample points within a district was further classified as per the ratio of the number of farmers with different landholding, which again was sub-classified on the basis of the gross cropped area under the primary crops in the respective districts. The details are provided in Annex 4.1.

Fig 4.1: land holdings



The sample survey conducted in the districts has been guided by the sample plan as far as possible. The survey had been conducted with assistance of the Gujarat Electricity Board officials, as access to village people was not possible otherwise. Thus actual implementation at the field level at times have resulted in slight variation in the number of samples actually collected vis-à-vis the requirement as assessed through sample plan due to availability and accessibility constraint.

Questionnaire development

The questionnaire was developed on the basis of the methodology to be adopted for determining the total consumption in the agricultural sector. Certain underlying driving factors were identified for the exercise namely, size of the land holding, cropping pattern and irrigation intensity, wattage of the irrigation pump set, water table depth, any other use of electricity for farming, such as threshers, winnowers, harvestors, etc., the usage pattern and the seasonality of use.

The basic objective of the survey was to acquire information on the electricity consumption by the consumer for the purpose of agriculture activities carried out. Thus based on the objective and subsequent model developed, the

questionnaire required cropping details of each farmer. The basic information elicited through the questionnaire was the crops cultivated by the farmer, the land area under each crop and the irrigation requirement of each crop. Besides, for an owner of a pump, information on the pump-size was also obtained. There was also a section addressing the usage of other electrical equipment for farming purpose, namely the type of equipment and the hours of usage.

In case of agriculture, the basic problem was the absence of meters. Thus, the units consumed as stated by the respondents could not be verified using bills. As a crosscheck to the pump-size stated by the respondents, therefore, information regarding the water table and also the flat tariff paid by the farmer was collected.

Other information collected included views on the power situation, the availability of water through water markets, etc. Futher, for the purpose of developing scenarios, the impact of Sardar Sarovar project on the irrigation requirements of the respondents was collected. The other significant information collected, not directly related to the exercise of projecting the consumption in this sector, was regarding their awareness of green power and their view regarding the same. The willingness of the consumer to promote green power through providing raw material and paying a higher cost was also queried.

Data analysis

The survey based on the questionnaire developed was carried out in the districts as mentioned in Annex 4.1. Though the intra-district coverage was a bit localised with the team travelling to a few villages around specific substations, but care was taken to ensure that the substations covered were predominantly rural. In terms of inter-district the coverage was as exhaustive as possible.

However at the outset, one needs to be cautious about the data available from the survey given the poor sensitivity of the consumers towards use of power. Information on land usage and crops grown was easily available from the consumers, as their recall regarding these was high. However details regarding irrigation pattern in terms of number of times irrigated, number of hours or days required for one irrigation, or hours required for per hectare irrigation lacked uniformity and clarity. The consumers many a times provided approximate values. Thus the ultimate analysis suffers partly due to this deficiency.

As is common knowledge, the details obtained from the survey can be broadly categorised on the basis of the cropping season. Thus the broad classification is three, the rabi, monsoon and kharif season. The primary crops grown as obtained from the sample details in these seasons are listed in the Table 4.3.

Table 4.3: The primary seasonal crops

Rabi	% of sample	Monsoon	% of sample	Kharif	% of sample
Wheat	69	Rice	26	Bajra	17
Cotton	18	Groundnut	25	Groundnut	8
Jera	18	Bajra	21	Jwar	4
Rye Castor	16	Jwar	21		
Maize	16	Cotton	12		
Sugarcane	4	Maize	5		
	4				

As seen from table 4.3, in Rabi season, wheat is the most commonly grown crop – with nearly 70 per cent of the sampled farmers growing the same, while rice and groundnut are the predominant crops grown in the monsoon season and bajra in kharif season. The other crops grown are cotton, sugarcane, maize, castor and rye. Though most of the crops are seasonal in nature, i.e. a cropping cycle is completed in one season, there are some which require more than one season for full cycle to be completed. Cotton and castor are an example, which require more than one season for one cycle – while cotton requires 8 to 10 months for one cropping cycle, castor requires 6 to 8 months. On the other hand, groundnut is another crop, which though requires only one season for its cycle, but can be cropped in two seasons.

Table 4.4: Crop-wise district distribution

Season	Crop-type	Predominant districts as per the sample collected
Rabi	Wheat	Sabarkantha (29%), Mehsana (22%), Junagadh (10%), Rajkot (9%)
	Cotton	Baroda (35%), Mehsana (24%), Kutch (7%), Sabarkantha (7%)
	Jera	Mehsana (23%), Rajkot (20%), Kutch (14%), Junagadh (13%), Sabarkantha (1[illegible]
	Rye	Mehsana (33%), Sabarkatha (14%), Baroda (8%), Kutch (7%)
	Castor	Mehsana (28%), Baroda (22%), Sabarkantha (19%), Kutch (11%)
	Sugarcane	Surat (65%), Navsari (23%)
Monsoon	Rice	Sabarkantha (46%),Ahmedabad (14%), Baroda (10%), Gandhinagar(9%)
	Groundnut	Junagadh (42%), Rajkot (31%), Kutch (24%),
	Bajra	Mehsana (37%), Junagadh (25%), Gandhinagar(9%), Sabarkantha (8%)

	Jwar	Mehsana (41%), Sabarkantha (23%), Junagadh (17%), Rajkot (11%)
	Cotton	Mehsana (27%), Rajkot (16%), Kutch (13%), Junagadh (12%), Gandhinagar (10%)
	Maize	Sabarkantha (85%)
Kharif	Bajra	
	Groundnut	
	Jwar	

The other interesting observation is the district-wise pattern of the crops, besides their seasonality. Though northern Gujarat is predominantly agriculture area, the districts in other regions grow certain specific crops. The specific soils type and water availability as well as climatic variations (if any) of the different districts are the underlying factors for determining the crop grown in the area. The table 4.4 provides the list of districts predominantly growing the primary crops. Mehsana and Sabarkantha are the two northern districts, which feature in most of the crops accounting for the maximum sample points. Its only groundnut and sugarcane that is not grown predominantly in these two northern districts. The former is grown primarily in Saurashtra region while the latter is grown in south Gujarat.

Besides crops, the other important factors that are reflected in the data pertain to land holding, water table depth and the pumpsize. Analysis of the sample shows that the percentage share of land holding is maximum for a holding of 1-3 hectare followed by 3-5 hectare. Greater than 10 hectare holding constitutes only 9 per cent of the sample (Table 4.5).

Table 4.5: Seasonal crops

Land-holding	Frequency	%
Less than 1 ha	98	14%
1ha to 3 ha	262	36%
3 ha to 5 ha	151	21%
5 ha to 7 ha	92	13%
7 ha to 10 ha	48	7%
Greater than 10 ha	68	9%
	719	

If further disaggregated into district level, the sample distribution with respect to land holding is as per Table 4.6. Thus we find that the district of Kutch has a high percentage of large land-holding farmers in the sample – while Mehsana and Sabarkantha – the predominantly agriculture regions have more small land

holding farmers.

Table 4.6: Districtwise land holding distribution of sample

	Ahmedabad	Anand	Baroda	Bharuch	Gandhi nagar	Kheda	Kutch
Less than 1 ha	2	7	30	0	3	8	[illegible]
1ha to 3 ha	3	6	32	2	17	7	[illegible]
3 ha to 5 ha	12	2	12	2	4	2	[illegible]
5 ha to 7 ha	6	1	7	4	4	1	[illegible]
7 ha to 10 ha	4	2	2	0	0	0	[illegible]
Greater than 10 ha	2	0	7	5	3	0	[illegible]
	29	18	90	13	31	18	[illegible]

	Mehsana	Navsari	Porbandar	Rajkot	Sabarkatha	Surat	[illegible]
Less than 1 ha	25	3	1	0	18	0	[illegible]
1ha to 3 ha	73	13	25	15	59	8	[illegible]
3 ha to 5 ha	26	2	21	17	33	7	[illegible]
5 ha to 7 ha	11	0	20	16	18	0	[illegible]
7 ha to 10 ha	0	7	8	9	4	1	[illegible]
Greater than 10 ha	3	1	9	6	5	2	[illegible]
	138	26	84	63	137	18	[illegible]

predominantly agriculture regions have more small land holding farmers. As per the sample, in most of the districts the number of farmers with land holding between 1ha to 3 ha is the highest as evident from table 4.6. Besides total land holding an analysis of the cropwise average landholding on a district basis is also carried out, which is provided in tabular form in Annex 4.2.

As far as water table and pump-size is concerned, the sample values reflect the actual trend, namely regions with deep water tables need to operate larger pump-sizes. Moreover the water table depths and pump-sizes also confirm approximately the secondary data as collected by the agriculture department. The district wise average water table depth and the average pumpsize is provided in the Table 4.7.

Table 4.7: Water table and pump-size district-wise

	Depth	Pump size
	FT	HP
Ahmedabad	298	21
Anand	118	13
Baroda	177	16
Bharuch	125	10
Gandhi nagar	392	28
Kheda	105	8
Kutch	338	32
Mehsana	529	51
Navsari	55	4
Porbandar	120	6
Rajkot	91	5
Sabarkatha	193	12
Surat	69	5
Valsad	53	3

The other important issue addressed in the survey, which was aimed to help in scenario development – was the impact of Sardar Sarovar project. Most of the respondents were quite apprehensive about the realisation of the project. However when coerced to reply – most of the respondents (nearly 90 per cent) were willing to take water from the canal for irrigation purpose. But they were of the view that they would need to install a pump, which many would be doing on a group basis rather than individual. The minimum pumpsize stated by most is a 5HP. Though the usage of ground water would be reduced, which might reduce the hours of pump usage, but on the other hand number of pumps being set up for surface irrigation will increase. Thus no assumption regarding the pump usage can be made. Only a qualitative statement can be made that the Sardar Sarovar project will not reduce the electricity consumption of the agriculture sector, on the contrary it might increase the consumption, given the number of new pump sets being installed.

Besides, this another general query made through the questionnaire was the consumer awareness and interest in green power. Most of the farmers were aware of the 'green power' though they were not conversant with the term. Sixty-six per cent of the consumers sampled were not interested in purchasing green power. Of the 34 per cent who were willing to buy green power most of them expressed that they would pay a maximum of 5 per cent more. Only around 10 respondents of the 720 people were willing to pay as high as 20 to 30 per cent more. Moreover when asked whether they would be interested in providing the farm waste for electricity production, around 87 per cent said that the waste is

used as cattle fodder. Of the rest around 10 per cent were willing to provide the waste for free, while the others wanted to sell the same.

Commercial Sector

The commercial sector represents largely the tertiary sector of the economy and comprises mainly service sectors like trade and commerce, transport, communication, education, medical services etc. The contribution of the tertiary sector to the state's gross domestic product is about 43 per cent with an annual growth rate of about 7.4 per cent which is quite substantial. The classification of population by economic activity according to the 1991 census reveals that main workers constitute about 34.12 per cent of the total population of the state of which share of the tertiary sector is about 22.4 per cent and there has been a continuous shift of workforce from primary to secondary and tertiary sectors. The above facts reveal that the sector is growing steadily and this may have an impact on the level of consumption of electricity as the two are generally related positively.

The commercial sector is highly heterogeneous in terms of economic activities. Apart from other diversities, the extent and pattern of consumption of electricity also varies a great deal across the sector. This is why for the purpose of electricity demand analysis, the sector has been decomposed into nine sub-sectors, viz, (i) communication, (ii) educational institutions, (iii) finance,insurance and business services, (iv) medical institutes, (v) restaurants and hotels, (vi) retail trade, (vii) storage and warehousing, (viii) transport and (ix) wholesale trade and the analysis is carried out separately for each of these sub-sectors.

Sampling details

The survey was conducted across the state so as to capture the structural diversities that may influence the pattern of electricity consumption in the sector. The procedure for selection of districts for the purpose of the survey was based on the concept of stratified random sampling where the stratification was done on the basis of the urbanization levels.

Table 4.8: Classification of districts on the basis of level of urbanisation

Circle	Conn load	% rural	% urban	Commercial Per capita conn load
Highly Urban				
Sabarmati	30.852	26.76%	73.24%	1.12
Moderately Urban				
Rajkot	154.631	50.91%	49.09%	1.41
Surat	74.495	49.48%	50.52%	1.61
Vadodara	89.276	55.95%	44.05%	1.16
Bhavnagar	41.740	62.63%	37.37%	0.81
Jamnagar	35.017	59.39%	40.61%	0.85
Predominantly Rural				
Surendranagar	18.539	69.80%	30.20%	0.88
Junagadh	40.368	65.72%	34.28%	0.83
Kachchh	48.988	70.01%	29.99%	1.49
Amreli	21.406	77.59%	22.41%	0.85
Kheda	53.548	78.02%	21.98%	0.82
Bharuch	29.744	78.23%	21.77%	0.95
Valsad	48.372	75.89%	24.11%	1.07
Mahesana	44.042	78.05%	21.95%	0.82
Banaskantha	40.189	88.38%	11.62%	1.10
Sabarkantha	17.931	88.08%	11.92%	0.64
Panchmahal	13.873	88.15%	11.85%	0.56

The rationale for stratification has been to survey one highly urban district, three of the moderately urban and four predominantly rural districts. Of the two highly urban districts, the survey has been done in Ahmedabad (highly urban), Vadodara, Surat, Porbander and Bhavnagar (moderately urban districts) and Mehsana, Sabarkantha, Kachchh and Junagadh(predominantly rural districts). These districts were selected so as to capture the high, medium and low per-capita connected load. The total sample size in this category, while ensuring statistical significance of the sample in each of the substrata was decided as 540. The survey was conducted with the help of GEB officials and the total number of samples collected for analysis of commercial sector demand were 563. The allocation of sample to the sub-sectors are done on the basis of proportional sampling, the proportion taken being equal to the population proportion of establishments within each commercial sub-sector. The work plan for the survey is given in annexe 4.2.

The particular types considered for survey under the category 'communication' are cyber café, telecom services and courier services. 'Educational institutions' include schools, colleges and training centres. For the category 'finance,

insurance and business services' the survey was conducted in banks, financial consultancies, chartered accountancy firms, credit societies and insurance organisations. 'Medical institutes' comprise small and large clinics, hospitals and nursing homes. For 'Restaurants and hotels' all kinds, small, medium and large have been taken into consideration so that the sample remains unbiased. 'Retail trade' category is again highly heterogeneous as it comprises a wide variety of shops of different sizes and selling different products. The pattern of usage of electricity also varies across these different kinds of shops, for example usage of electricity in a jewellery shop or an ice cream parlour is much higher generally than that in an ordinary stationary shop. The survey, therefore, has covered almost all types of shops, taking into consideration both product categories as well as size. 'Storage and warehousing' as the name suggests comprise mainly cold storages and warehouses of different goods. For the category 'transport', the survey has been carried out in several transport companies, travel agencies, automobile companies. For 'wholesale trade' as the name suggests, data has been collected from wholesale traders of different goods.

Questionnaire Development:

The questionnaire for the commercial sector begins with usual questions on demographic details such as 'name of the establishment', 'address', 'telephone number', 'fax number' etc. The types of establishment were mentioned in the questionnaire and the enumerator was required to tick the appropriate one. Information regarding number of people working for the establishment was obtained. To have an idea of how many hours the establishment operates daily, the 'starting time' and 'closing time' were recorded. Also information is obtained on the number of working days in a week which is essential particularly for estimating commercial consumption as most of the commercial establishments do not operate for all the seven days of a week. Then information on number of appliances used by the respondent for different end-uses, their average hours of usage in a day, months of usage in a year as well as time of usage were also collected. This part of the questionnaire is most important to calculate the consumption in the sector. Further, the electricity bills were collected from the respondents to verify the actual units of electricity consumed and bill amount in each month of the current year. To estimate the unmet demand, questions pertaining to back-up arrangements are framed. This includes 'type of back-up arrangement', whether diesel genset or inverter, its capacity, hours of usage in a day/month and for a cross check, cost of generation per day/month.

The questionnaire also has a subjective part at the end, where questions related to 'green power' were framed. The objective is to know how many of the respondents in the sample are concerned about the growing problem of pollution, aware of environment friendly 'green power', and were willing to pay for it.

Data analysis

The primary data has been collected mainly with the objective of having an idea of the end-use demand for electricity. The specific end-uses considered are (a) lighting, (b) space conditioning, (c) refrigeration and water purifying and (d) office equipment & others.

From the survey, it is obtained that commercial consumers use incandescent bulbs, mercury lamps, neon lamps, spot light, fluorescent tubes and compact fluorescent lamps for lighting purposes; and ceiling fan, table fan, air conditioner, air cooler (very few) and exhaust fan for space conditioning. Use of refrigerator is very common in a good number of commercial establishments. Many of them use aqua-guards for water purifying. Of the office equipments, computers, printers, scanners, photo-copier are widely used. 'Others' include mostly water pumps and television.

In the commercial sector, demand for electricity is conceived of as being driven by income or sales turnover. However at the questionnaire pre-testing stage it was experienced that the respondents were highly unwilling to disclose information on income or sales turnover. In place of income, it is generally employment which can be most appropriately used for the purpose. Thus an attempt has been made to obtain a consumption per employee norm from the sample. The norm has been analysed at various levels of disaggregation so as to capture the variation in the pattern of consumption across the sector.

The consumption per employee norm for each commercial category obtained from sample analysis is given in table 4.9:

Table 4.9 : Norms of consumption per employee as derived from survey

Commercial Category	Consumption per Employee (kWh/year)
Communication	628.43
Educational Institutions	126.00
Finance, Insurance and Business Services	254.17
Medical Institutes	582.76
Restaurants & Hotels	632.20
Retail Trade	297.66
Storage & Warehousing	1263.02
Transport	225.34
Wholesale Trade	225.03

From the above table, it is observed that, the consumption per employee norm for storage & warehousing category is the highest which is quite justifiable as in this category there is an enormous and continuous usage of electrical appliances especially for the purpose of cooling and refrigeration. Storage & warehousing is followed by communication and restaurants & hotels. Usage of computers and air conditioners mostly in cyber cafes and additional usage of water heating appliances like geyser and kitchen appliances like microwave ovens, mixers, grinders, juicers etc. in hotels and restaurants apart from lighting and space conditioning load account for the relatively high value of the norm in these two sub-sectors. In case of 'medical institutes' too the norm was found to be relatively high. One reason for this is the fact that in hospitals and nursing homes, hours of usage of appliances especially those of space conditioning like fans and air conditioners is greater than the rest of the categories. Also usage of high capacity appliances like life support systems, ECG machines, geysers etc. are common in hospitals and nursing homes. For other categories like 'educational institutes', 'retail trade', 'wholesale trade', 'transport' and 'finance, insurance and business services', consumption per employee is more or less same and much lower than the other categories as consumption of electricity is largely for the general purpose of lighting and space conditioning only with very little usage for purposes of refrigeration, cooking, water heating etc.

To have an idea of how the norm varies across the districts an analysis of district-wise consumption per employee is done, the result of which is shown in the table 4.10.

Table 4.10: District-wise consumption per unit of employment:

Sl.No.	District	Consumption per Employee (kWh/year)
1	Ahmedabad	397.77
2	Bhavnagar	218.76
3	Bhuj	295.24
4	Sabarkantha (Himmatnagar)	505.87
5	Junagadh	163.00
6	Mehsana	193.78
7	Porbander	303.01
8	Surat	332.74
9	Vadodara	473.01

The sample analysis shows that the average consumption per employee, as given in table 4.10, is found to be higher in the urban districts, viz, Ahmedabad, Vadodara, Surat and Porbander with the exception of Bhavnagar and Himmatnagar. It is observed that Bhavnagar though an urban district has low consumption per employee whereas Himmatnagar, inspite of being a predominantly rural district accounts for a significantly high value of consumption per employee, infact the highest among all the districts. In the discussion part of the next table (Table 4.11) detailing the district-wise end-use norm, an attempt has been made to explain the reason behind this exceptionally high consumption per employee norm in a rural district like Himmatnagar .

Within each district an end-use-wise break up of consumption per employee is analysed and the same is presented in the table below:

Table 4.11: End-use wise consumption per employee by districts (kWh/year):

Sl. No.	District	Lighting	Space Conditioning	Office Equipment & Others	Refrigeration & Water Purifying
1	Ahmedabad	134.26	146.38	45.16	67.96
2	Bhavnagar	74.19	106.67	22.75	15.14
3	Bhuj	88.89	111.89	81.81	12.65
4	Himmatnagar	63.27	93.37	321.31	27.91
5	Junagadh	66.20	74.27	8.95	13.58
6	Mehsana	54.18	99.55	21.02	19.03
7	Porbander	112.35	122.78	58.74	9.15
8	Surat	130.96	120.59	29.40	51.79
9	Vadodara	259.44	148.40	28.82	36.36

Table 4.11 reveals that a major share of consumption per employee is accounted for by lighting and space conditioning in most districts. The fact that consumption per employee for the most common end-uses, viz., lighting and space conditioning are highest in Ahmedabad, the highly urban district, followed respectively by the moderately urban Vadodara, Surat and Porbander and the

predominantly rural Bhuj, Bhavnagar, Junagadh, Himmatnagar and Mehsana leads us to conclude that consumption is highly related to the level of urbanisation. The consumption per employee norm for 'office equipment and other' in Himmatnagar is unusually high. This is perhaps an outlier which is either due to misreporting in one or more questionnaires or due to a bias that may have occurred in the selection of the sample in that particular district. As explained earlier, the exercise of primary data collection gives the researcher a qualitative feel for the subject under study on the basis of which we recognise this as an outlier. Two samples collected in Himmatnagar, both in the category of storage & warehousing are found to be using high capacity motor and water pump for longer hours and particularly their consumption has contributed to the high value of consumption per employee norm for the district.

Again within each commercial sub-sector, an end-use analysis of consumption per employee is carried out, results of which are depicted below:

Table 4.12 : End-use wise consumption per employee by commercial sub-category (kWh/year):

Sl. No.	Commercial Category	Lighting	Space Conditioning	Office Equipment & Other	Refrigeration & Water Purifying
1	Communication	99.97	235.89	279.40	13.17
2	Educational Institutes	34.40	59.70	33.54	2.55
3	Finance, Insurance & Business Services	68.51	124.97	57.43	3.26
4	Medical Institutes	131.11	300.24	19.80	131.61
5	Restaurants & Hotels	289.38	185.85	86.68	70.29
6	Retail Trade	132.27	110.42	10.50	44.49
7	Storage & Warehousing	85.53	85.60	1091.77	0.119
8	Transport	57.06	80.90	85.34	2.05
9	Wholesale Trade	99.71	108.24	12.08	5.00

Table 4.12 shows that with the exception of 'restaurants & hotels' and 'retail trade', all other categories the relative consumption due to space conditioning is higher than that due to lighting which is actually justifiable as the capacity of space conditioning appliances like air conditioners and air coolers are much higher than lighting appliances, viz., bulbs and tubes and also the time of usage of the former is generally more than the latter as lights are usually switched on in absence of daylight, mostly in the evening for three to four hours only. 'Retail trade' category is very heterogeneous as it includes shops of all sizes, small, medium and large as well as selling different products. It was found in general that jewellery shops or boutique shops were lit up with large number of high-

powered bulbs and tubes leading to a high variance in the lighting requirements across shops, whereas space conditioning requirements do not vary much. This may be the reason for higher lighting load than space conditioning load in retail trade category. The same reason may be put forward for hotels and restaurants as well. The sample analysis gives that in case of 'communication' consumption due to 'office equipment & others' is higher than in other commercial categories, due to greater usage of computers, printers etc. particularly in cyber cafes. This is highest in case of 'storage and warehousing' probably due to the same reason as discussed earlier.

The survey reveals possession of diesel gensets by a number of commercial consumers as a provision for back up in case of power failure. The districts in which this is observed in large numbers are Porbander, Surat and Vadodara. Usage of back-up power, as obtained from analysis of the entire sample is 81233.63 kWh/year. This unmet demand is about 7% of the actual demand in the entire sample.

To have a feeling of the feasibility of setting up green power projects in the state with regard to consumer's willingness to pay for it, the number of commercial consumers in the sample who are concerned about pollution and willing to pay for green power is calculated. Of the 563 consumers surveyed, 85 percent reported concern for the problem of pollution whereas only 30 percent are willing to pay for environment friendly green power.

›omestic

ıtroduction

The domestic sector consumes almost 12 per cent of total electricity consumption of the state. As highlighted earlier, the economy of Gujarat ranks high in terms of the various economic indicators in comparison with the other states of the country. Further, the per capita consumer expenditure in the state is higher than the all-India average as given in table 4.13. Also as has been indicated in table 4.1 earlier, the per capita consumption of electricity in the state is nearly double of the all-India average.

Table 4.13 : Monthly per capita consumer expenditure (in Rs.) *

	Gujarat	India
Rural	303	281
Urban	454	458
Combined	355	327

* according to NSS-50th round July-June, 1993-94

Sampling details

The stratification in the domestic sector was be done on the basis of the urbanization levels as in the case of the commercial sector. Table 4.14 gives classification of the various districts according to the level of urbanisation and their respective connected load along with per capita connected load.

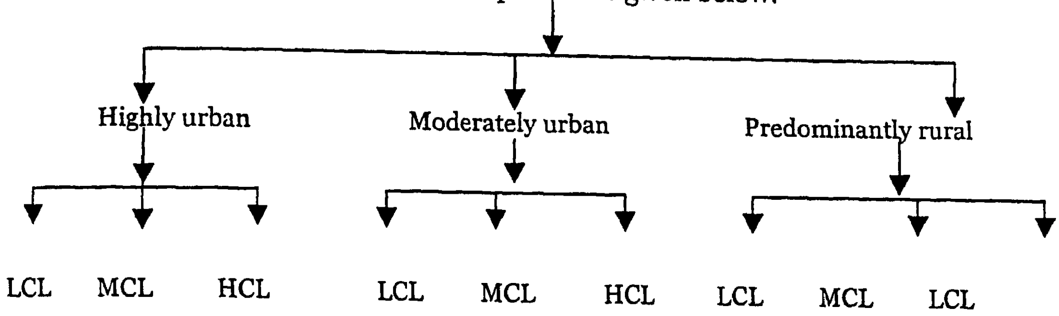
Table 4.14 : Classification of districts on the basis of level of urbanisation

Circle	Connected load	% rural	% urban	Domestic per capita conn load
Highly urban				
Sabarmati	114.307	26.76%	73.24%	0.51
Moderately urban				
Rajkot	315.675	50.91%	49.09%	0.66
Surat	265.921	49.48%	50.52%	0.80
Vadodara	412.539	55.95%	44.05%	0.74
Bhavnagar	182.929	62.63%	37.37%	0.56
Jamnagar	155.006	59.39%	40.61%	0.65
Predominantly rural				
Surendranagar	112.67	69.80%	30.20%	0.73
Junagadh	191.089	65.72%	34.28%	0.60
Kachchh	150.28	70.01%	29.99%	0.70
Amreli	106.509	77.59%	22.41%	0.50
Kheda	263.816	78.02%	21.98%	0.57
Bharuch	150.088	78.23%	21.77%	0.61
Valsad	254.455	75.89%	24.11%	0.65
Mahesana	202.857	78.05%	21.95%	0.45
Banaskantha	118.811	88.38%	11.62%	0.48
Sabarkantha	117.811	88.08%	11.92%	0.46
Panchmahal	144.308	88.15%	11.85%	0.63

The stratification in the domestic sector has been done on the basis of the urbanization levels and the connected load. The underlying assumption in the methodology used in this sector is that urbanization levels effect the pattern of electricity consumption in domestic sector. Through the sample design, an attempt has been made to capture this variation in pattern of electricity consumption.

At the first level stratification, the sample is stratified into one highly urban circle, two moderately urban districts and three predominantly rural districts. At the second level stratification, these districts are further sub-stratified according to the connected load in these districts.

A flow diagram of the sample selection process is given below.



Here LCL, MCL and HCL represent low connected load, medium connected load and high-connected load. Within each of the substrata the sample is selected so as to capture low, medium and high-income groups.The total sample size in this category was 540 (30*3*6) and to ensure statistical significance at least 30 observations were taken in each sub-strata. The sample survey was conducted with the help of the officials of the Gujarat Electricity Board. There has been a slight variation in the number of sample actually collected vis-à-vis the requirement as assessed through sample plan due to availability and accessibility constraints.

The total sample size in this category was 540 (30*3*6) as to ensure statistical significance at least 30 observations were taken in each sub-strata. The sample survey was conducted with the help of the officials of the Gujarat Electricity Board. There has been a slight variation in the number of sample actually collected vis-à-vis the requirement as assessed through sample plan due to availability and accessibility constraints.

Questionnaire development

The methodology used in the case of the domestic sector relies on driving factors such as appliances owned and their usage patterns. The basic objective of the survey was to acquire information on the electricity consumption made by the consumer for the various domestic activities. Thus based on the objective and subsequent model developed, the questionnaire required to get information on the appliance owned by a household, wattage of each appliance, appliance penetration levels, usage patterns and the seasonality in the usage of the appliances. The various end-uses considered in this sector was lighting, cooking, refrigeration, space heating or space cooling, water heating, and the other uses like television, music system, computers, mixer grinder etc.

The other information collected included household income and expenditure. The respondents were requested to produce the previous month's bill to verify the consumption stated by the respondents. The questionnaire included a section on the back-up facility to assess the unmet demand in this consumer category. The questionnaire also included a section on the respondent's views o the power situation. The other significant information collected was consumer awareness on green power and their willingness to pay higher tariffs for the same.

Data analysis

As explained earlier, the consumption of electricity is derived from the appliances owned and their usage patterns. However at the outset, it needs to be highlighted that though the respondents could easily report the appliances owned, the recall of the usage patterns of various appliances was found to be quite low. In particular, the respondents found it difficult to report the hours c use of fans and lights in the various rooms in the household. The consumers many a times provided approximate values. This induces a certain degree of error in the final analysis.

The analysis assumes that the consumption patterns of people would vary witl heir income levels. However, since most respondents did not feel comfortable reporting their income, the monthly bill amount has been used as a proxy to categorize the respondents into 5 income categories. The underlying assumpti was that people with higher incomes tend to have larger houses and greater number of appliances and therefore have greater consumption of electricity. I each category, the consumption pattern is classified according to the end uses i.e. lighting consumption, cooling consumption, water heating consumption, ε others. The 5 categories of consumers are given in table 4.15 below.

Table 4.15: Slab-wise classification

Class	Category	Slab (MU p.m)	Approximate bill (Rs p.m)
A	High Electricity Consumption	>300	>1065
B	High-Medium Electricity Consumption	>200 and <300	>655 & <1065
C	Medium Electricity Consumption	>100 and <200	>295 & <655
D	Low-Medium Electricity Consumption	>50 and <100	>145 & <295
E	Low Electricity Consumption	<50	<145

Slab wise analysis (sample analysis)

Using the various end uses as reported by the respondents, the average electricity consumed per household by various categories of consumers is compiled in the Table 4.16. The category-wise consumption by each of the end uses as given in table 4.16 below, confirm to the general hypothesis that the higher slabs have higher consumption. The interesting observation though is that the major contributor to this high consumption is usage of refrigerators.

Table 4.16: Slab wise yearly consumption per household

	Average Units consumed yearly (per household)					Average Units
Category	Lighting	Cooling	Water heating	Refrigeration	Others	consumed Yearly
A	831	905	79	1613	506	3933
B	564	593	42	1197	288	2685
C	374	358	7	39	138	1366
D	242	199	0	227	75	742
E	147	126	1	122	40	436

Lighting consumption

The appliances that are classified under this head are bulbs, tube lights and CFLs. The penetration levels and contribution of these appliances to the overall consumption as obtained from the sample is shown in the table 4.17. The CFL penetration is seen to be still quite low and only restricted to the high tariff slabs. The other interesting observation is that the penetration of bulbs is higher in the two high tariff category and the lowest tariff category compared to tube lights. Though the variation is very marginal, but the same could be looked into in further details.

Table 4.17: Various Appliances and its contribution to lighting consumption

Category	Average per household	Bulbs	Tube Lights	CFLs
A	Penetration	5.2	4.8	1.2
	Watts [1]	76	40	13
	Percentage[2] Contribution	62%	36%	1%
B	Penetration	3.6	4.3	0.93
	Watts	62	40	13
	Percentage Contribution	56%	42%	1%
C	Penetration	3.1	3.9	0.38
	Watts	46	40	13
	Percentage Contribution	43%	56%	1%
D	Penetration	2.1	2.5	0.23
	Watts	27	40	11
	Percentage Contribution	38%	61%	2%
E	Penetration	2.4	2.1	0
	Watts	24	40	0
	Percentage Contribution	30%	70%	0%

Aggregating we get, the consumption for lighting contributes around 21%in category A and B, whereas in category D and E it is around 34% as given in table 4.18. This may be because in category A and B, the general awareness regarding conservation of power by the use of CFLs etc. is generally higher. Thus even though they consume more electricity for lighting in terms of units, the percentage of electricity consumed for lighting is lower. Further, the penetration level of appliances like, refrigerators, computers, mixer grinders, microwave ovens etc., is significantly higher in these categories. The percentage share of the electricity consumption of these appliances is high in categories A and B, while it is relatively insignificant in categories D and E with the largest difference being in the consumption by refrigerators. Table 4.18 below gives the lighting consumption as a percentage of the total consumption in various categories.

Table 4.18: Contribution of lighting consumption

Category	Average monthly Lighting Consumption	Average Monthly Consumption	Lighting Consumption (Percentage)
A	69	328	21%
B	47	224	21%
C	31	114	27%
D	20	62	33%
E	12	36	34%

[1] Average Watts as per the sample
[2] Contribution to the consumption due to lighting

Cooling consumption

The appliances that are classified in this category are different types of fans, coolers and air conditioner. The penetration levels and contribution to the overall consumption is shown in the table 4.19.

Table 4.19: Penetration level

Category	Fans Per household	Percent contribution	AC penetration	Percent Contribution	Number of households having ACs
A	5	75%	63%	25%	40%
B	4.15	83%	14%	27%	11%
C	3.64	97%	5%	2%	5%
D	2.14	99%	1%	1%	2%
E	2	100%	0%	0%	0

Aggregating the above we get that the consumption of electricity for the purpose of space cooling accounts for 23% in category A and B, whereas in category D and E it is 29% as given in table 4.20. The reason for this would be similar to that in the case of lighting. It may be noted at this point that most of the electricity consumed by category E is due to lighting and space cooling.

Table 4.20: Consumption due to Cooling

Category	Average monthly Cooling Consumption	Average Monthly Consumption	Cooling Consumption (Percentage)
A	75	328	23%
B	49	224	22%
C	30	114	26%
D	17	62	27%
E	11	36	29%

Water heating consumption

The appliances classified under this category are geysers and immersion rods. It may be noted that the consumption through geysers is more then 95% of the total water heating consumption.

The consumption of electricity for heating water accounts for 2% of the total consumption in category A and B, 1% in category C consumers, while in category D and E it has zero contribution (table 4.21). This variation is due to the difference in penetration levels of geysers and immersion rod.

Table 4.21: Contribution of Water Heating Consumption

Category	Average monthly Water Heating Consumption	Average Monthly Consumption	Water Heating Consumption (Percentage)
A	7	328	2%
B	3	224	2%
C	1	114	1%
D	0	62	0%
E	0	36	0%

Refrigeration

The penetration levels, wattage and usage pattern of refrigerators in the various categories is given in the table 4.22 below

Table 4.22: Penetration level of refrigeration

Category	Average Watts	Penetration level	Summer Hours	Winter Hours	Greater then 1 Refg
A	265	100%	22	19	20%
B	235	98%	23	20	3%
C	163	88%	22	17	0%
D	150	54%	17	12	0%
E	110	50%	10	3	0%

The electricity consumption due to refrigeration accounts for 41% pf the total electricity consumed in category A, 45% in category B, 36% in category C, 31% in category D and 28% in category E (table 4.23). This disparity may be attributed to the wide variation in the penetration levels, wattage and usage pattern of the refrigerators as given in table 4.23.

Table 4.23: Consumption due to refrigeration

Category	Average monthly Consumption due to refrigeration	Average Monthly Consumption	Consumption due to Refrigeration (Percentage)
A	134	328	41%
B	100	224	45%
C	41	114	36%
D	19	62	31%
E	10	36	28%

Other consumption

The various appliances classified under this head, their penetration levels and contribution to consumption can be seen in tables 4.24 and 4.25 below. The major contributor under this classification is television. The penetration level and share of electricity consumed by televisions in the total electricity consumed is given in table 4.24.

Table 4.24: Penetration level of TV and consumption share

Category	Number of TVs per household	Percentage contribution to consumption	Households having more than 1 TV
A	1.27	64.6%	28%
B	1.04	70.6%	5%
C	0.96	72.8%	1%
D	0.80	77.0%	0.7%
E	0.81	94.0%	0%

The consumption due to other appliances in the various categories is given in table 4.25 below.

Table 4.25: Consumption due to other appliances

Category	Average monthly Consumption due to other appliances	Average Monthly Consumption	Consumption due to other appliances (Percentage)
A	42	328	13%
B	24	224	11%
C	12	114	10%
D	6	62	10%
E	3	36	9%

Industry

Introduction

Gujarat is considered one of the most industrialized states of India with the secondary sector growing at a rate much higher than the national average. Industrial consumption is approximately 43% of the total sale of electricity. Further, the state has relatively easy access to oil and gas coupled with a very liberal captive power policy. These factors have led to an increase in generation by captive power plants in the state to 11345 MUs in FY2000 of which 188 MUs was sold to GEB. The total sale of power to industry by GEB, AEC and SEC totalled to 11037 MUs in the same year. Thus, 50% of the total demand for electricity is met by captive power plants.

Sample design

The industries in the state have been classified into product categories as per the Annual Survey of Industries (ASI) classification. The total sample size in this category, choosing 3% of the total number of industries, so that the heterogeneity in each product category may be captured, was calculated as 440. The number of industries to be surveyed in each category was apportioned on the basis of the total number of units in that category. The industries in each category were selected to represent both LT and HT consumers. The units in each category were selected with the help of the Gujarat Electricity Board

officials. However, during the execution of the survey, 453 industries were surveyed. The classification of the industries along with the number of units surveyed in each category is given below:

Table 4.26: Industry Classification

Sl. No.	Industry	Total number of units in the State	Number of units surveyed
1.	Food Products	996	42
2.	Beverages, Tobacco and Tobacco Products	360	5
3.	Cotton Textiles	1048	13
4.	Wool, Silk and Synthetic Fibre Textiles	1333	41
5.	Jute Hemp and Mesta Textiles	15	0
6.	Textile Products (including wearing apparel other than footwear)	294	7
7.	Wood and Wood Products, Furniture and Fixtures	781	19
8.	Paper and Paper Products and Printing Publishing and Allied Industries	585	18
9.	Leather and Fur Products (except repair)	65	1
10.	Rubber, Plastic, Petroleum, and Coal Products	984	28
11.	Chemical and Chemical Products (except products of petroleum and Coal)	2421	77
12.	Non-metallic mineral products	1270	38
13.	Basic Metal and Alloys industries	1073	32
14.	Metal Products and Parts except Machinery and Transport Equipment	1197	47
15.	Machinery and Machine Tools and Parts except Electrical Machinery	1117	47
16.	Electrical Machinery Apparatus Appliances and Supplies and Parts	543	17
17.	Transport equipment and Parts	207	8
18.	Other Manufacturing Industries	367	8
19.	Others	21	5
	Total	14677	453

Questionnaire development

It was envisaged that the driving forces for consumption of electricity would be the output or turnover of the industry and the technology mix in the industry. The end-uses considered in this sector are lighting and space conditioning, pumps and motor drive, compressors, furnaces and heating equipment and other machinery. The above factors would be represented in the electricity consumption per value of output, which would be the norm used in this sector. Thus the questionnaire was designed to gather data regarding the electricity consumption of the unit over the past year along with the total value of output of the industry. Further, data regarding the various end-uses in the unit were to be

collected along with the hours of use of each of the end-uses. Moreover, to get a feel for whether there is a scope of a sudden increase in the demand, the questionnaire included a section on whether the respondent had applied for an additional load and if so whether it has been sanctioned. Also the questionnaire included a section on data regarding captive power plant/power back-up facilities. The questionnaire also attempted to elicit information regarding the probable future shift toward captive power or a shift to other states in response to a tariff increase in the near future. A section regarding the respondents' willingness to pay a higher price for green power was included so as to get a feel for the financial feasibility of green power projects in the state.

Data analysis

The sample was designed using the ASI classification of industries (sample design). It was found that out of this sample 369 industries work through the year while the others are seasonal in nature. Further only 86 industries are continuous process industries.

Extensive data regarding the equipment used in the various industries was collected in the survey. However the equipment usage being dependent on the output requirements as per the orders in hand for the unit, the hours of use for many machines was provided as an approximation. Also, the respondents found it difficult to record the number of hours certain equipment such as Xerox machines are used as the usage varies as per the need. Further, many respondents were not able to give the wattage of certain equipment such as computers. The survey encountered resistance from many respondents when asked to report the value of their output and thus this question has not been answered by many. Many respondents were unable to provide electricity bills for the past year and have provided bills for a few months. While 96 respondents have not reported their total value of output, only 24 respondents reported their monthly consumption for the entire year.

It was found that in the sample only 17 people have applied for additional load and only 10 of these applications have been sanctioned. However many respondents mentioned that there were requests pending for surrender of load

mainly due to the depression in the economy as well as the increasing trend in power tariffs.

9 respondents in the sample had captive power plants. While none of these respondents had plans of expanding the existing units, 13 respondents had plans of setting up new captive plants in the near future. On the other hand, 119 respondents have backup facilities.

Contrary to the other sectors, it was found that most respondents were aware of the increasing pollution levels and the existence of green power as an environmentally friendly option. Though 414 respondents expressed concern regarding the increasing level of pollution, only 117 respondents said that they would be willing to pay a higher price for green power. Most respondents felt that the higher tariff to pay for green power would be unfair if imposed on only a few people. This higher tariff should be imposed on all consumers across consumer categories.

Since most respondents were unable to give electricity bills for an entire year, the available monthly information has been used to calculate the average monthly consumption of electricity for that industry. This average was used to calculate the norm for electricity consumption in that category viz. total annual consumption/total value of output. Industries which have not reported the total value of output have been dropped from this analysis. It may be argued that the 'net value added' of the unit would serve better in the norm instead of value of output as the net value added from various industries sums up to the GDP from industry. However, during the pretest of the questionnaire it was found that the respondents were unable to report the net value added of their unit. The value of output, on the other hand, was reported by a majority of the respondents. Further, the value of output is also reported by secondary sources such as the Annual Survey of Industries. Also, the net value added was found to be a consistent percentage of the value of output across the various categories of industries. Thus the movements in the value of output would be a good indicator of the growth of the industry.

An analysis of the end-uses of the various industries was done on the basis of the details of various equipments provided by the respondents. These equipments were classified into five major categories viz. lighting and space conditioning, motor and pump load, compressors, heating and furnace equipment and others. It was found that many respondents had been unable to report the wattage of

some of the equipment. The total connected load for various industries was studied under the above mentioned categories using the list of equipment as provided by the respondents. The percentage of connected load under these categories is given in the table below(Table 4.27).

Table 4.27: Percentage share of various categories of end-uses

Category	Lighting and space conditioning	Motor and pump load	Furnace and heating equipment	Compressor	Others
Food products	5.10%	49.70%	2.95%	32.68%	9.57%
Beverages, tobacco and tobacco products	4.60%	29.86%	0.00%	60.90%	4.65%
Cotton textiles	5.20%	52.16%	2.45%	8.67%	31.51%
Wool, Silk and Synthetic fibre textiles	4.53%	44.16%	4.58%	0.17%	46.56%
Textile products (including wearing apparel other than footwear)	5.50%	69.34%	0.00%	4.71%	20.46%
Wood and wood products, furniture and fixtures	7.41%	72.27%	0.85%	0.11%	19.37%
Paper and paper products and printing publishing and allied industries	2.27%	74.31%	5.04%	1.20%	17.18%
Rubber, plastic, petroleum and coal products	1.10%	54.64%	24.23%	2.15%	17.88%
Chemical and chemical products (except products of petroleum and coal)	2.49%	56.74%	3.55%	8.75%	28.47%
Non-metallic mineral products	0.89%	88.69%	1.68%	7.76%	0.98%
Basic metals and alloys industries	1.39%	69.29%	25.77%	3.55%	0.00%
Metal products and parts except machinery and transport equipment	1.93%	81.61%	6.24%	5.86%	4.36%
Machinery and machine tools and parts except electrical machinery	2.38%	46.87%	8.71%	42.04%	0.00%
Electrical machinery apparatus appliances and supplies and parts	5.67%	81.65%	10.75%	1.92%	0.01%
Transport equipment and parts	9.18%	33.36%	13.81%	2.12%	41.53%
Other manufacturing industries	1.10%	8.65%	0.10%	4.94%	85.21%
Others	19.34%	16.35%	3.91%	53.42%	6.99%

Thus, we observe that in all the categories motor and pump load is the largest electricity consuming category. The motor and pump load varied between 8.65% and 88.69%. The minimum was found in the category 'other manufacturing industries' where a large number of welding machines are used. These are grouped under the category 'others' which is the largest electricity consuming group in this category. The average percentage of motor and pump load across categories was found to be 54.69%.

The lighting load varied between 0.89% and 19.34% with the average across industry classes being 4.71%. This category includes the electricity consumed by

the bulbs, tube lights, mercury lamps, and other lighting equipment along with air coolers, air conditioners, water dispensers, water coolers, water purifiers, ceiling fans, pedestal fans, and exhaust fans.

The compressor load varied between 0.11% and 60.9%. The maximum, 60.9%, was found in the class 'beverages, tobacco and tobacco products'. The other categories that have a relatively high compressor load are 'food products' (32.68%), 'machinery and machine tools and parts except electrical machinery' (42.04%) and 'others' (53.42%). On leaving out these categories, the average compressor load across categories is 3.99%.

The 'furnace, ovens and heating equipment' load was found to be largest in the 'Basic metals and alloys industries' and 'Rubber, plastic, petroleum and coal products' classes. The average among the other categories is 4.31%.

The connected load of the various categories per the end uses as given in the survey was calculated. The connected load of the various categories as a percentage of the total connected load as per the calculations is given in the table below (Table 4.28). Besides, as per data taken from the Annual Survey of Industries (ASI), the percentage share of the electricity purchased by the various industries is also given in the same table (Table 4.28).

Table 4.28: Percentage share of connected load of various categories

	Category	Connected load (as per survey)
1	Food products	5.99%
2	Beverages, tobacco and tobacco products	1.29%
3	Cotton textiles	1.17%
4	Wool, Silk and Synthetic fibre textiles	3.01%
6	Textile products (including wearing apparel other than footwear)	0.78%
7	Wood and wood products, furniture and fixtures	0.87%
8	Paper and paper products and printing publishing and allied industries	2.17%
10	Rubber, plastic, petroleum and coal products	3.50%
11	Chemical and chemical products (except products of petroleum and coal)	14.79%
12	Non-metallic mineral products	19.18%
13	Basic metals and alloys industries	8.31%
14	Metal products and parts except machinery and transport equipment	8.89%
15	Machinery and machine tools and parts except electrical machinery	23.55%
16	Electrical machinery apparatus appliances and supplies and parts	0.83%
17	Transport equipment and parts	1.47%
18	Other manufacturing industries	3.82%
19	Others	0.37%

As per data taken from the Annual Survey of Industries (ASI), the percentage share of the electricity purchased by the various industries is given in the table 4.29.

Table 4.29: Percentage share of electricity purchased of various categories (as per ASI)

	Category	Electricity purchased FY1997
1	Food products	5.70%
2	Beverages, tobacco and tobacco products	0.10%
3	Cotton textiles	10.22%
4	Wool, Silk and Synthetic fibre textiles	13.08%
5	Jute, Hemp and Mesta Textiles	Included in category 18
6	Textile products (including wearing apparel other than footwear)	0.53%
7	Wood and wood products, furniture and fixtures	0.07%
8	Paper and paper products and printing publishing and allied industries	2.93%
10	Rubber, plastic, petroleum and coal products	2.73%
11	Chemical and chemical products (except products of petroleum and coal)	34.27%
12	Non-metallic mineral products	13.51%
13	Basic metals and alloys industries	6.88%
14	Metal products and parts except machinery and transport equipment	1.28%
15	Machinery and machine tools and parts except electrical machinery	Included in category 16
16	Electrical machinery apparatus appliances and supplies and parts	4.63%
17	Transport equipment and parts	0.50%
18	Other manufacturing industries	0.30%
19	Others	3.25%

The district-wise distribution of the industries in the survey is given below:

Table 4.30: Number of Industries surveyed in each district

District	Number of industries Surveyed
Jamnagar	15
Rajkot	96
Surendranagar	0
Bhavnagar	0
Amreli	0
Junagadh	18
Kachchh	7
Mehsana	60
Banaskantha	0
Sabarkantha	0
Gandhidham	5
Ahmedabad	44
Nadiad	34
Panchmahals	0
Baroda	47
Bharuch	21
Surat	49
Valsad	37
Dangs	0

Of the various industries surveyed in Jamnagar, the majority were basic metal and alloys and metal products and parts industries except machinery and transport equipment. Rajkot also was found to have a majority of the above mentioned industries alongwith machinery and machine tools and parts except electrical machinery industries. Mehsana was found to have a majority of Food products and Leather and fur products industries alongwith machinery and machine tools and parts except electrical machinery industries. It may be noted here that Mehsana, Ahmedabad, Nadiad and Baroda were found to be the predominantly industrial districts wherein a mix of all types of industries was found. Ahmedabad was found to have many food product industries and metal products and parts industries except machinery and transport equipment industries. Baroda and Valsad were found to have many chemical and chemical products industries and Surat leads in the production of Wool, Silk and Synthetic fibre textiles.

Annexe 4.1

Work plan for all sectors

	Agriculture	Domestic	Commercial	Industry
Valsad	30	108		*
Surat	40		93	*
Vadodara	80	175	67	*
Kheda	40			
Sabarkantha	140	50	59	
Mahesana	140		60	*
Gandhinagar	30			*
Ahmedabad	30	48	104	*
Kachchh	50		17	
Junagadh	80	81	88	
Bhavnagar		78	52	*
Rajkot	60			*
Total	720	540	540	440

Annexure 4.2

Agriculture sector work plan

Broad classifn	Connected load	District	Landholding type	%	No. of q're		Crops		
							Wheat	Cotton	
Saurashtra	256 8%	Rajkot	1	10%	6		3	3	
		60 56	2	30%	18		9	9	
			3	40%	24		12	12	
			4	15%	9		4	5	
			5	5%	3		1	2	
				Total	60				
							Wheat	Cotton	G'nut
	419 13%	Junagadh	1	20%	16		10	3	3
		80 92	2	30%	24		16	4	4
			3	30%	24		16	4	4
			4	15%	12		8	2	2
			5	5%	4		2	1	1
				Total	80				
							Wheat	G'nut	
Kachch	233 7%	Kachch	1	5%	2.5	3	1	2	
		50 51	2	20%	10	10	3	7	
			3	40%	20	20	5	15	
			4	25%	12.5	12	3	9	
			5	10%	5	5	2	3	
				Total	50	50			
							Rice	Wheat	
North Gujarat	226 7%	Ahmedabad	1	20%	6	6	4	2	
		60 50	2	25%	7.5	8	5	3	
			3	30%	9	9	6	3	
			4	15%	4.5	4	3	1	
			5	10%	3	3	2	1	
				Total	30	30			

							Rice	Wheat	Bajri
		Gandhinagar	1	40%	12	12	4	6	2
			2	27%	8.1	6	2	2	2
			3	27%	8.1	6	2	2	2
			4	5%	1.5	3	1	1	1
			5	1%	0.3	3	1	1	1
				Total	30	30			
							Wheat	Bajri	N-food
	695	Mehsana	1	33%	46		10	6	30
	21%	140	2	30%	42		9	5	28
		153	3	30%	42		9	5	28
			4	5%	7		2	1	4
			5	2%	3		1	1	1
				Total	140				
							Wheat	Bajri	Cotton
	694	Sabarkantha	1	30%	42		30	5	7
	21%	140	2	30%	42		30	5	7
		153	3	30%	42		30	5	7
			4	8%	11		8	1	2
			5	2%	3		1	1	1
				Total	140				
							Rice	Wheat	Bajri
Middle Gujarat	189	Kheda	1	50%	18		12	3	3
	6%	40	2	25%	9		7	1	1
		42	3	18%	7		5	1	1
			4	5%	3		1	1	1
			5	2%	3		1	1	1
				Total	40				
							Rice	Wheat	Cotton
	347	Vadodara	1	32%	26		4	5	17
	11%	80	2	28%	22		3	4	15

		76							
			3	30%	23		3	4	16
			4	8%	6		1	2	3
			5	2%	3		1	1	1
				Total	80.4				
							Rice	S'cane	
South Gujarat	135	Surat	1	32%	12		3	9	
	4%								
		40	2	26%	10		3	7	
		30							
			3	32%	12		3	9	
			4	8%	3		1	2	
			5	2%	3		1	2	
				Total	40				
							Rice	Wheat	Othr-food
South Hills	73	Valsad	1	56%	16.8	13	5	3	5
	2%								
		30	2	20%	6	6	3	1	2
		16							
			3	18%	5.4	5	2	1	2
			4	5%	1.5	3	1	1	1
			5	1%	0.3	3	1	1	1
				Total	30	30			
TOTAL	3267	720							

Commercial sector work plan

	Highly Urban	Moderately Urban		Predominantly Rural					
Commercial Sub-sectors	Ahmedabad	Surat	Vadodara	Bhavnagar	Kachchh	Junagadh	Mahesana	Sabarkantha	Total
Wholesale Trade	7	12	3	2	0	3	5	3	35
Retail Trade	64	57	40	32	0	64	39	32	328
Restaurant/Hotel	3	3	3	2	3	3	0	2	19
Transport	10	7	5	5	7	0	7	5	46
Storage & Warehousing	5	2	2	2	0	2	2	2	17
Communication	3	3	3	2	0	5	2	2	20
Banking, Insurance, Business Services	5	3	3	2	2	0	2	2	19
Educational Institutions	5	3	5	2	5	8	0	8	36
Medical Institutions	2	3	3	3	0	3	3	3	20
Total	104	93	67	52	17	88	60	59	540

Annex 4.4

Penetration level in various categories of consumers (% of consumers possessing the appliance)

Categories	Penetration level in various categories of consumers				
	A (>300 units p.m.)	B (200 to 300 units p.m.)	C (100 to 200 units p.m.)	D (50 to 100 units p.m)	E (<50 units p.m.)
Washing Machine	47.50	37.04	24.37	4.20	4.17
Televisions[1]	127.50	104.94	94.92	79.72	80.56
Computers	35.00	15.85	9.64	2.10	1.39
Printers	10.00	4.88	2.54	0.00	1.39
Audio Systems	35.00	26.83	15.74	10.49	5.56
Water Pumps	32.50	29.27	6.60	4.20	1.39
Iron	47.50	35.37	25.89	22.38	18.06
Water Purifier	30.00	10.98	7.61	2.10	0.00
Electrical Heater	17.50	1.22	1.02	2.10	0.00
OTG	5.00	1.22	0.51	0.00	0.00
Microwave	5.00	3.66	2.54	0.70	1.39
Mixer Grinder	92.50	89.02	63.45	38.46	25.00
Juicer	12.50	9.76	8.12	3.50	2.78
Electric Kettle	0.00	1.22	0.00	0.00	0.00
Hot Plate	2.50	0.00	0.00	0.00	0.00
Toaster	25.00	13.41	5.08	1.40	0.00
Vacuum Cleaner	17.50	2.44	2.03	0.00	0.00

[1] More then 100% penetration indicates that the consumers are having more then one TV in the house.

5 Primary Model

5.1 Introduction

After a thorough analysis of the primary data as discussed in the previous chapter it was endeavoured to feed the findings of the analysis into models of electricity demand forecasting. Thus an extensive research was carried out to develop such models so as to estimate the current demand for electricity in each of the four identified sectors, viz, agriculture, commercial, domestic and industry as well as to forecast their future requirement. In each sectoral model demand for electricity has been related to a relevant variable and thereby electricity consumption norm in terms of that variable has been established. The estimates of the norms are obtained through analysis of sample survey data on the assumption that the selected sample would be representative of the population. In the following sections the analytical models adopted for assessment of demand in each of the four identified sectors have been described in details.

5.2 Agriculture

5.2.1 Introduction

The agriculture sector in most of the states in India face an inherent problem of arriving at an accurate consumption figure, given that most of the consumers are unmetered. Though the reform process is attempting to initiate a major drive in metering all consumers, it will take some time for realising the objective totally. In the meantime, the assessment of electricity consumption in the agriculture sector will have to be based on assumptions and theoretical calculation as carried out by most of the existing and erstwhile state electricity boards. Since this number is not easily verifiable, in most cases the consumption of electricity in the sector has been inflated by inclusion of loss and theft figures of the other sectors. With the onset of the new regulatory regime in the sector, the nuances are coming to light. Given the unreliability of the historical data for the sector, projection of the demand for electricity in the sector remains an intriguing task. Thus the need for a primary model based projection for this sector has been the focus for a while. However since the exercise still depends on some secondary

data, the accuracy of the forecast cannot be guaranteed, but the attempt can be stated to be the first serious step taken to obtain a reasonable assessment of atleast the current consumption of the sector.

5.2.2 Model

The agriculture model developed to assess the current consumption as well as to make a future projection of the demand for electricity in the sector has been based entirely on the requirement of irrigation for different types of crops cultivated in the state. Ideally the pumpset ownership and growth in the pumpset energisation should have been the driving factors for determining the consumption in the sector and also to project the demand. But since secondary data on pumpsize wise ownership details is not easily available and moreover, most of the times the data reported by the consumers on the current pumpsize is questionable – this direct method could not be adopted.

As already mentioned in the previous chapter, the primary survey carried out enabled in collecting information regarding irrigation details for each crop-type in the different regions of the state for each sample consumer. The model thus developed attempted to relate the irrigation requirement of the crops to the pumping requirement and hence the electricity consumption.

Thus given the information by each consumer on the crop (j) in a specific district (k) in terms of

- number of irrigation required per month (i_{jk}) for a particular crop,
- the number of months (m_{jk}) required for one cropping cycle along with
- hours (h_{jk}) required for each irrigation of the total cropped area and
- the acreage (a_{jk}) under the crop,

the irrigation intensity (I_{jk}) in terms of hours of irrigation required per hectare can be calculated. The irrigation intensity is the basis or norm used for estimating the electricity requirement for total irrigation in a cropping cycle of a crop.

Thus mathematically if interpreted using the above defined variables, the norm would be simply:

$$I_{jk} = \frac{i_{jk} \times m_{jk} \times h_{jk}}{a_{jk}}$$

Thereafter equipped with the knowledge of irrigation norm for a specific crop for a particular district and also the average pumpsize (P_{jk}) used for irrigation purposes in the district (as already presented in the previous chapter), the electricity consumption norm per acre can be calculated. Explicitly on multiplying the horse-power of the pump with the irrigation norm and the conversion constant 0.746, we obtain the kilowatt-hour of consumption per acre (C_{jk}) for irrigation of a particular crop type.

$$C_{jk} = I_{jk} \times P_{jk} \times 0.746$$

The crop-wise , region-wise C_{jk} as obtained through survey data analysis and applied for the projection exercise in this study is summarised and provided in the Annex 5.1. However there has been approximations applied to some of the districts as all the districts were not covered during the survey. The survey has attempted to capture all the agro-climatic zones and the results obtained in one of the districts in a particular agro-climatic zone could easily be extended to the neighbouring districts in the same agro climatic zone without losing much authenticity. In case all the districts were captured individually, the effort involved would have been much greater than the marginal improvement that might be obtained in the results.

The above norm thus obtained for each district and crop can be applied on the available secondary data on the total irrigated area for a specific crop in a particular district (A_{jk}), to estimate the total electricity consumption for irrigation of the crop-type. Thereafter summing over all the crop-types, the total current electricity consumption in the entire agriculture sector of the state can be obtained.

$$\textit{Total agriculture consumption: } C_a = \sum_j \sum_k C_{jk} \times A_{jk}$$

5.2.3 Projection

The projection of future demand for electricity is based on projection of the total cropped area under each crop. The implicit assumption is that the norm will continue to remain the same in the business as usual scenario and the future demand for electricity of the sector will be driven by the movement in the total cropped area under each crop.

The past data from 1980-81 to 1991-92 is available in the Agriculture Statistics, Gujarat, a Directorate of Economics and Statistics, GoG publication, on the

cropped area districtwise for each crop-type. The broad categories of the crops reported here are the major crops namely, rice, wheat, bajra and jowar under foodgrain, grams under pulses and besides other cash-crops like, cotton, sugarcane, groundnut and sesamum. For projection purpose first the share of each district in the total area under each croptype is determined, which is found to be more or less constant. Thereafter the share of total area under a particular crop-type as a percentage of total area under cultivation is determined.

The total cropped area is projected using trendline and thereafter the same is allocated amongst the different crop-types using the percentage ratio obtained from past data. The area thus obtained under a particular crop-type is then further distributed amongst each district in the ratio of the area under district to total area in the state for that crop-type as reflected in the past data. However as for projection of total cropped area, it is assumed that the percentage growth in the area would have stagnated to around 1.1 per cent and that the area would saturate in the near future. Thus the growth in the area is very marginal.

However the entire cropped area in each region is not subject to irrigation. The Statistical Abstract of Gujarat, 1998 provides a percentage share of irrigated area in cropped area in each district for 1994-95 beyond which information on the same is not available. So for the purpose of projection beyond 1994-95, it has been assumed that the percentage share of irrigated area in cropped area would increase at a compound annual rate of 10% from 1995-96 onwards in all the districts and saturate at 75%. The assumption is based on the premise that due to severe drought and depletion of water table in the state for the past seven years there has been an observed growth in pumpsets energised which is bound to have brought more areas under irrigation.

5.2.4 Results

The final figures for the agriculture consumption as obtained by the above methodology is available on a crop-wise and district-wise basis. The same is summed up to provide a consolidated crop-wise agriculture electricity consumption figure. The time series data on cropped area for the sector is available for some primary crops only, which is not exhaustive of the total cropped area. The broad classification made for the cropped area in terms of crops cultivated is as per Table 5.1.

Table 5.1: Crops included for consumption calculation

S.N	Crop-classifications	Crops
1	Cereals	Rice
		Wheat
		Jowar
		Bajra
		Maize
		Others
2	Pulses	Gram
		Others (Mung, Tuar etc)
3	Oilseeds	Groundnut
		Sesamum
		Rapeseed & Mustard
		Others (Castor)
4	Cash-crops	Sugarcane
		Cotton
5	Others	Vegetables
		Spices etc.

The 'other' factor in each of the broad crop classification is taken care of by making certain assumptions regarding the same on the basis of secondary information in literature on the state and also from observation made during the survey. For example in the oilseeds category, castor is a dominant crop which is not listed in the cropped area classification made in the government publications. Hence for 'other oilseeds' category the norms of castor as obtained from the primary survey is applied, while the district wise classification is made as per Sesame, as both the crops have a more or less similar cropping requirement. Similarly assumptions are made regarding the 'other' categories in the other crops classifications to obtain corresponding electricity consumption figures. The same is presented in Table 5.1. The growth in electricity consumption over the years as projected is not very high, partly because of the assumption made with respect to saturation in the cropped area.

The estimated total consumption in the agriculture sector for the year 2001 (year of survey) is 13684 MU. As already mentioned earlier, the agriculture consumption data as reported in secondary sources cannot be used for validation of the agriculture consumption value as obtained through the model. Thus for validation, the T&D loss study being carried out for Gujarat by TERI titled, 'Gujarat Transmission and Distribution Loss Estimation' is referred to. This study has metered the predominantly rural substations in all the zones in Gujarat and calculated the agriculture consumption for the state. A comparison of the estimate of agricultural consumption of electricity obtained under the

present study for the year 2001 (year of survey) with that obtained by the 'T&D loss estimation' study for the same year is presented in table 5.2.

Table 5.2: Comparison of estimated consumption of the agriculture sector as per present study with that of 'Gujarat T&D Loss Estimation' study

Year 2001	Gujarat T&D Loss Estimation	Present Study	Percentage variation
Consumption (MU)	13445	13684	2

The demand for electricity of the agriculture sector as forecasted for the short (2002-03), medium (2006-07) and long (2011-12) run are provided in the Table 5.3.

Table 5.3: Total demand for electricity (MU) in agriculture sector as forecasted

Year	Demand (MU)
2002-03	14418
2006-07	16436
2011-12	17941

5.3 Commercial

5.3.1 Introduction

The commercial sector unlike the agriculture sector pertains mostly to the urban conglomeration and electricity installations are well metered. However information on units of electricity consumed as reported in the electricity bills of consumers reflect essentially the restricted demand, it fails to take into account the demand that is existent during power outages. Therefore such information do not pertain to the actual electricity demand of a consumer. Moreover the commercial sector is subject to high level of commercial losses or thefts in the form of faulty meter, illegal connection etc. Therefore estimates of requirement of electricity in the sector on the basis of units of consumption as recorded by electricity meters will inevitably be lower than the actual requirement. Hence it was envisaged that a consumer survey based analysis which would enable an end-use analysis of demand would be a better approach to form an idea of the actual demand for electricity in the sector at present as well as to predict the future demand of the sector.

5.3.2 Model

The model for estimating the current electricity demand in the commercial sector as well as for predicting the future demand is developed in a way to

capture the influences of structural factors more specifically that of growth in employment on consumption of electricity. The idea behind this was that growth in employment would actually reflect growth of the sector, which in turn would influence the requirement of electricity in the sector. Thus the basic model defined for estimating electricity demand is the product of electricity intensity in terms of consumption per employee and the level of employment, i.e.

$$C_c = \alpha_c \times n_c \qquad \text{... (1)}$$

where, C_c is Commercial sector electricity Demand

α_c is the electricity demand per employee

n_c is the number of employees

Here the electricity intensity in terms of consumption per employee is the norm/basis for estimating demand for electricity in the commercial sector. A numerical estimate of this norm is obtained through an analysis of the primary survey data along with available secondary data.

From international experience it is learnt that electricity intensity in terms of consumption per unit floor area under commercial establishment is more stable than electricity intensity in terms of consumption per employee. The reason put forward is that the variation in electricity intensity per unit area within a particular commercial category is smaller than the variation in terms of consumption per employee. For instance, a luxury hotel with leisure facilities will use per employee substantially more electricity than a small hotel but the difference in terms of electricity consumption per square metre floor space will be smaller.

However, due to non-availability of sufficient data on area under commercial establishments at the state level, consumption per unit area could not be used as a norm in the present study.

The commercial sector is highly heterogeneous with a wide variety of economic activities and the pattern of electricity consumption varies immensely across the sectors. This is why a bottom up approach is adopted for assessment of demand in this sector. According to this approach the demand for electricity is estimated

at two levels of disaggregation and then summed up to obtain the aggregate demand of the sector. The levels of disaggregation considered are

- commercial establishments/sub-sectors
- end-uses of electricity

Thus for the analysis, the sector was decomposed by economic activity into nine sub-sectors, viz,

1. Retail trade
2. Wholesale trade
3. Restaurants and hotels
4. Communication
5. Storage and warehousing
6. Finance, insurance and business services
7. Transport
8. Educational Institutes
9. Medical Institutes

Demand for electricity of each of the above sub-sectors is estimated separately and then summed up to obtain the aggregate demand of the sector as a whole. Assessment of demand for electricity in each sub-sector is done on the basis of the model (1) as discussed earlier. Accordingly at the sub-sectoral level the norm defined is the average consumption per employee in that sub-sector. A numerical estimate of this norm has been obtained through an end-use analysis of the sample data collected through primary survey of commercial consumers. As has already been discussed in the previous chapter, in the commercial sector, electricity is used for four main purposes, viz, (a) lighting, (b) space conditioning, (c) refrigeration and water purifying and (d) office equipment and others (which include water pump, television, etc.). For each and every sample, consumption due to these end-uses has been estimated separately and then aggregated to arrive at the total consumption of electricity by that sample. Now, for the i^{th} sample in the j^{th} commercial sub-sector, consumption of electricity due to a particular type of end-use k, is formulated as

$$c_{ijk} = m_{ijk} \times w_{ijk} \times h_{ijk} \times m_{ijk} \times d_{ijk} \times 4 \qquad \forall i = 1 \rightarrow n_j$$

where, c = annual consumption

m = number of electrical appliances used

w = wattage of appliances

h = average daily hours of usage of appliance

m = number of months of usage in a year

d = number of working days in a week

n_j is the sample size in the j^{th} commercial category

Taking into consideration that commercial establishments do not operate for all the seven days of a week, the multiplicative factor 4 is applied to the model to obtain the annual consumption under the general assumption of a four-week month. Thereafter, the total consumption (c_{ij}) of electricity by the i^{th} sample point in the j^{th} commercial sub-sector is obtained simply by summing the consumption (c_{ijk}) as obtained above over all the end-uses.

$$c_{ij} = \sum_k c_{ijk} \qquad \forall i$$

The total consumption thus obtained for each sample is thereafter used to calculate the per employee consumption norm in each sub-sector. Supposing l_{ij} to be the number of employees in the i^{th} sample of the j^{th} commercial sub-sector, the norm for the j^{th} sub-sector has been formulated as,

$$AC_j = \frac{1}{n_j} \sum_i \left(\frac{c_{ij}}{l_{ij}} \right) \qquad \forall j$$

where AC_j is the average consumption per employee in commercial sub-sector j. The consumption per employee norm thus obtained for each sub-sector through sample data analysis is presented in annex 5.2

Subsequently, current demand in the commercial sub-sector is given by,

$$C_j = AC_j * N_j \qquad \forall j$$

where N_j is the state level employment in the jth commercial sub-sector. To estimate state level employment in each commercial sub-sector recourse has been taken to available secondary data.

A digression

Information on employment are provided in the Statistical Abstract of Gujarat prepared and published by the Directorate of Economics and Statistics, Government of Gujarat. However data pertaining to main workers in the tertiary sector are available not at same the level of (sub-sectoral) disaggregation as considered in the present study but under three broad classification as mentioned below:

Category I : retail trade, wholesale trade, restaurants & hotels and finance, insurance & business services

Category II : transport, storage and communication

Category III : educational institutes and medical institutes

The above data being available, the sample proportion of employment in each sub-sector has been applied to the population to obtain the state level employment in each of the nine commercial sub-sectors.

For example,

$$\begin{pmatrix} \text{poplemplin} \\ \text{transport} \end{pmatrix} = \frac{(\text{emplin transport})}{(\text{emplintransport} + \text{emplinstorage} + \text{emplincommunication})} * \text{emplincategoryII}$$

(sample estimate) (population estimate)

Finally, aggregating the sub-sectoral demand (C_j), we arrive at an estimate of the total demand in the sector. Symbolically,

$$\textit{Current demand in the sector} = \sum_j C_j$$

The estimate of commercial consumption thus obtained when compared with the actual consumption for the same period showed only a marginal variation of nine per cent higher than the actual.

Table 5.4: Comparison of actual with estimated consumption of the commercial sector in Gujarat

Year 2001	Actual*	Estimated	Percentage variation
Consumption (MU)	1482	1610	9

* includes consumption from GEB, AEC and SEC as per the tariff order/filing

5.3.3 Projection

For forecasting future demand for electricity in the commercial sector, the norm is estimated at the sectoral level, simply by the method of aggregation. It is

assumed that the sectoral norm is simply the average consumption per employee in the commercial sector.

$$norm\ estimate = \frac{estimated\ commercial\ sector\ consumption\ in\ the\ current\ year}{estimated\ commercial\ sector\ employment\ in\ the\ current\ year}$$

$$\begin{pmatrix} Commercial\ sector's \\ demand\ for\ electricity \end{pmatrix} = (above\ norm\ estimate) * (overall\ employment\ level\ in\ the\ sector)$$

Considering this base year norm to continue in the future as well, forecasts of future demand is obtained by projecting the future employment level (methodology used for projecting the future level of employment is discussed subsequently). This is the business-as –usual scenario where any increase in future level of demand is solely explained by a rise in the employment level in the sector. The implicit idea is that a rise in the employment level will indicate an increase in macroeconomic output or income, broadly, growth of the sector, which will consequently lead to an increase in consumption of electricity in the sector.

Alternatively, it may be expected optimistically that the population will be aware of undertaking conservation measures and thus move towards more efficient appliances. From a literature survey of various research work it is found that over a period of 10 years efficiency level generally improves by 5-10 percent. In this study too we have considered one scenario, viz, efficiency improvement of 12 percent over the next 10 years. This is expected to cause a decrease in the average consumption per employee norm from its business as usual level by the percentage assumed for efficiency improvement each year. Thereby consumption in the sector will decline.

Before presenting the results, a discussion is made on the technique adopted for projecting the level of employment in the commercial sector. The Directorate of Economics and Statistics, Government of Gujarat records the population of Gujarat decomposing it into workers and non-workers and further classifying workers into main and marginal workers. Main workers are being further disaggregated by economic activity into cultivators, agricultural labourers, livestock and forestry, mining and quarrying, manufacturing and processing, construction, trade and commerce, transport, storage and communication and

workers in other services. Decennial data for the years 1961, 1971, 1981 and 1991, on number of workers in each category are compiled by the Directorate of Economics and Statistics, Govt. of Gujarat, and reported in 'Statistical Abstract Of Gujarat State'. In the present study all these data have been utilized for projecting the number of workers in the commercial sector.

The approach has been to project the share of main workers in the each of the three sectors, viz, primary, secondary and tertiary. Cultivators, agricultural labourers, workers in livestock and forestry constitute the primary sector work force, secondary sector workforce includes workers in mining and quarrying, manufacturing and processing, and construction and within tertiary sector are considered workers in trade and commerce (category 1), transport, storage and communication (category 2) and other services, viz, educational and medical services (category 3). Three period data, 1971, 1981 and 1991 are considered and the shares of workers, non-workers, main workers, marginal workers, as well as main workers in primary, secondary and tertiary sectors are projected by fitting logarithmic trend. Within the tertiary sector, again, share of workers in category I, category II and category III (as mentioned earlier) are projected by the same procedure. The projections are normalised so as to ensure consistency. Precisely, the model is:

Number of workers in category i = ***(share of category i in tertiary sector workforce)*** * ***(tertiary sector workforce)***

Tertiary sector workforce = *(share of tertiary sector in main workers)* * *main workers*

Main workers = *share of main workers in population* * *population*

The estimates of population given in Census of India, a Govt.of India publication is used for the purpose of forecasting. Projected shares of main workers in different sectors of the state are given in table 5.5. Following the past trend it is obtained that there will be a continuous decline in share of worker in the primary sector vis-à-vis the secondary and tertiary sectors.

Table 5.5: Sectoral share in main worker population (in percentage)

Year	Primary Sector	Secondary Sector	Tertiary Sector
2001	58.760	18.429	22.810
2002	58.679	18.475	22.846
2003	58.600	18.519	22.881
2004	58.524	18.562	22.914
2005	58.450	18.604	22.947
2006	58.378	18.644	22.978
2007	58.308	18.683	23.009
2008	58.239	18.722	23.039
2009	58.173	18.759	23.068
2010	58.108	18.796	23.096
2012	57.983	18.866	23.151

Table 5.6 shows the projected number of workers in the tertiary sector with sub-sectoral break up.

Table: 5.6: Main Worker Population in Tertiary Sector

Year	Category I	Category II	Category III	Total
2001	1528766	660667.9	1647444.5	3836878
2002	1554350	672348.9	1672700.7	3899400
2006	1662607	721649.8	1780035.6	4164292
2011	1795897	782444	1911845.9	4490187

5.3.4 Results

Following the above methodology, average consumption per employee in the commercial sector is obtained as 419.58 kWh per year. The projected employment level in the commercial sector for the year 2001 is 3836878. Demand for electricity in the commercial sector, as per the above model, for the year 2001(year of survey) is estimated to be 1609.89 MU. This when compared to the actual consumption of the state, the variation is marginal at 9 per cent (higher than the actual) as mentioned earlier. The analysis reveals that the maximum of the total demand, about 40% comes from storage and warehousing units, followed by retail trade which accounts for 16% of the demand. Medical institutes comes next in the order with a share of 14% . Contribution of educational institutes and restaurants and hotels are almost same with 10% and 11% respectively. Share of finance,insurance and business services is very less, only 4%. Wholesale trade and transport, each account for a meagre 2% demand and communication accounts for only 1% of the total commercial demand. Table 5.7 provides the commercial sub-sector wise consumption figures for the current year.

Table 5.7: Commercial sub-sector wise consumption for the year 2001

Commercial sub-sector	Consumption (MU)	Percentage share
Communication	18.53	1
Educational Institute	158.35	10
Finance, Insurance, Business Services	64.80	4
Medical Institutes	227.65	14
Restaurants & Hotels	177.18	11
Retail Trade	251.43	16
Storage & Warehousing	652.65	40
Transport	25.79	2
Wholesale Trade	33.50	2
Total	1609.88	100

As has already been mentioned, a scenario of improvement in efficiency of appliances is considered, whereby the average consumption per employee norm is expected to decrease, and thereby total consumption in the sector will decline. The scenario assumes a 12 per cent improvement in efficiency by 2012 as has already been mentioned earlier. The demand for electricity of the commercial sector as forecasted under the alternate scenarios, for the short (2002-03), medium (2006-07) and long (2011-12) run are provided in the Table 5.8.

Table 5.8: Total demand for electricity (MU) in commercial sector as forecasted

Year	Business As Usual	Improvement in Efficiency
2002-03	1636	1620
2006-07	1747	1726
2011-12	1884	1858

5.4 Domestic

5.4.1 Introduction

In the household sector electricity has wide usage apart from being commonly used for lighting and space conditioning. To make life more comfortable various new household appliances of electricity are being regularly invented and the general trend of people is to acquire them once they obtain the capacity to pay/invest. Like the commercial sector, in the domestic sector too installations are being metered. Thus the quantum of consumption by the sector is available as reported in the bills. But as is common knowledge, the actual consumption is

usually much higher than the reported. Power outages as well as commercial losses or thefts in the form of faulty meter, illegal connections, etc account for the difference. It is therefore necessary to estimate the actual consumption not only to assess the extent of theft but also to have a perception of the need of the sector. Thus a model has been developed on the basis of primary survey data to anlayse and forecast the demand for electricity in the sector.

In the following section the details of the model that is used for arriving at the likely estimates of demand is discussed.

5.4.2 Model

As has already been discussed in the primary data analysis chapter the various end-uses that have been considered for the domestic sector analysis are (a) lighting, (b) space conditioning, (c) water heating, (d) refrigeration and (d) Others. Besides, for this analysis the consumer base is classified/ segmented in accordance with the existing residential tariff slabs adopted by the Gujarat Electricity Board. Thus the model developed attempts to determine the end-use pattern of the consumer segments in each tariff slab through an analysis of the primary survey data. The result is then used to project the consumption of the sector as a whole.

Various parameters that are considered for the analysis are number of appliances, wattage of the appliances, average hours in a day they are used and the number of days they are used in an year. Consumption (C_{ijk}) per sample is calculated by multiplying the number of appliance (A) of a particular type/ end use (k), their wattage (W), number of hours used in a day (H) and number of days used in a year (D).

$$C_{ijk} = A_{ijk} \times W_{ijk} \times H_{ijk} \times D_{ijk} \qquad \forall i = 1 \rightarrow n_j$$

where, n_j is the sample size in the j^{th} domestic category

Thus the total consumption (C_{ij}) of electricity for the i^{th} sample point in the j^{th} domestic category is simply obtained through aggregating the consumption over all the end-uses as obtained through the above formulation.

$$C_{ij} = \sum_k C_{ijk} \qquad \forall\, i$$

Thereafter the average consumption per household (c_j) for a particular tariff category of domestic consumer is determined by dividing the total consumption

for that category obtained through summing up C_{ij} for each 'j' and dividing the same by the number of households in that category as available from the sample.

$$c_j = \frac{1}{n_j} \sum_i C_{ij} \qquad \forall j$$

After obtaining the average consumption per household c_j from the sample, for the five different tariff categories (as defined in GEB tariff structure), the total domestic sector consumption (C_d) is calculated by multiplying the above norm by number of total residential consumers (N_j) in each category as available from the population in the state. The underlying assumption is that the sample is representative of the population.

The data regarding the number of residential consumers in Gujarat have been taken from three providers of electricity in Gujarat i.e. Gujarat Electricity Board (GEB), Ahmedabad Electricity Company (AEC) and Surat Electricity Company (SEC). Adopting the above model, the result obtained for the year 2000-01 is shown in table 5.9.

Table 5.9: Category wise consumption in domestic sector for the year 2001

Category	Number of consumers	Estimated Consumption (MU)
E (<50)	4691262	2045
D (50-100)	1335325	987
C (100-200)	639146	872
B (200-300)	121772	327
A (>300)	74501	293
Total	6862007	4523

The result is validated with the actual consumption data for the same year, 2001 (year of survey). The estimated consumption when compared with the actual consumption for the same period in Gujarat shows a 7 per cent variation from the actual. The figures are presented in table 5.10.

Table 5.10: Comparison of actual with estimated consumption of the domestic sector in Gujarat

Year 2001	Actual*	Estimated	Percentage variation
Consumption (MU)	4232	4523	7

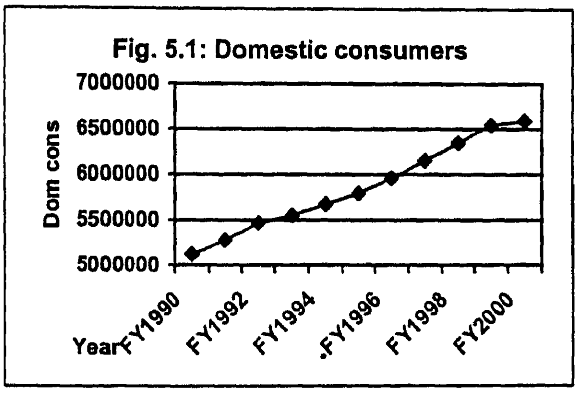
* includes consumption from GEB, AEC and SEC as per the tariff order/filing

A 10% variation from actual is quite acceptable. Therefore the model may reasonably be used for the purpose of forecasting the future demand for electricity of the residential sector in the state.

5.4.3 Projection

Broadly, there are two parameters for projecting the residential demand according to the model specified, namely, the average consumption in each of the category of residential consumers and second the estimated slab-wise number of residential consumers in the state.

Assuming that average consumption norm in each residential category will continue to remain at the same level in the future as well, the number of



consumers in each tariff slab in future years is forecasted to arrive at forecasts of future demand for electricity in the sector. For estimating slab-wise consumers in future years a trendline (fig. 5.1) is fitted to the past data series on the total number of consumers as available from the GEB.

The number of consumers as seen in chart 1 is increasing consistently for past eleven years following a linear trend. Thus extrapolating the past trend, forecasts of future number of consumers in the domestic sector have been arrived at. Results show that number of consumers increased by 2.6 percent in the initial years and then slowly declined to 2.1 percent in the last couple of years. The growth rates obtained for future years are presented in table 5.11.

Table 5.11: Forecast of consumers in domestic sector

Year	Projected number of consumers	Growth rate
FY2001	6862007	
FY2002	7044248	2.7%
FY2003	7226489	2.6%
FY2004	7408729	2.5%
FY2005	7590970	2.5%
FY2006	7773211	2.4%
FY2007	7955452	2.3%
FY2008	8137693	2.3%
FY2009	8319933	2.2%
FY2010	8502174	2.2%

FY2011	8684415	2.1%
FY2012	8866656	2.1%

For obtaining the slab-wise break-up of residential consumers, the past pattern of distribution is observed and adopted for the present study. To be more specific, a three-year average distribution of residential customers of Gujarat Electricity Board and Ahmedabad Electricity Board are considered separately for the purpose. Due to non-availability of data regarding tariff-slabwise customers of Surat Electricity Company, the same distribution of residential customers as of AEC has been assumed. The assumption is justifiable as both Ahmedabad and Surat are highly urban districts with similar socio-economic features. Moreover, number of residential consumers in SEC is only around 5% of the total number of consumers in the state. So variations in distribution of consumers under SEC would not lead to a significant variation in the overall result. The percentage share of the consumers in each slab as calculated is presented in the Table 5.12.

Table 5.12: Percentage distribution of number of domestic consumers in GEB and AEC & SEC

Slab	AEC+SEC	Percentage distribution	GEB	Percentage distribution
<50	552153	46%	4139109	73%
51-100	342332	28%	992993	18%
101-200	233482	19%	405664	7%
200-300	48829	4%	72943	1%
>300	34396	3%	40105	1%
Total	1211193	100%	5650814	100%

Applying the above percentage distribution the slab-wise number of consumers in the sector is forecasted for the short, medium and long run as provided in Table 5.13.

Table 5.13: Slab-wise consumers in the domestic sector

Category	E	D	C	B	A	
Years		Slab wise projected consumers				Total
FY2002	4815853	1370788	656121	125006	76480	7044248
FY2006	5314214	1512642	724018	137942	84394	7773211
FY2011	5937165	1689960	808890	154112	94287	8684415

5.4.4 Results

The final consumption figures for residential sector is obtained by multiplying the slab-wise number of consumers with the slab-wise average consumption per

household, the latter being obtained through end-use analysis of primary data as discussed earlier. The results are shown in table 5.14.

Table 5.14: Total demand for electricity (MU) in domestic sector as forecasted

	E	D	C	B	A	
Year	Slab Wise Projected Sales MU					Total
FY2002	2100	1013	895	336	301	4643
FY2006	2317	1118	987	370	332	5124
FY2011	2589	1249	1103	414	371	5725

5.5 Industry

5.5.1 Introduction

The industrial sector unlike the other sectors is more organised in terms of availability of consumption data from the utility, especially for consumers belonging to the high-tension category. Moreover the incidence of theft in this HT category is also negligible as stated by experts in the sector. However the other category of industrial consumers namely those belonging to low tension category have some large volumes of reported thefts, which was aimed to be captured through the primary survey by calculating the actual consumption based on end-use details. But as already mentioned in the earlier chapter, the survey itself was a difficult exercise due to manifold reasons. Firstly, the information solicited by the industry was not always accurate primarily because of the innumerable types of machines in use, with not only varying motor sizes but also varying usage pattern. Moreover the usage of these machines were demand driven, which is again a highly uncertain variable. Secondly given the list of machinery used across the sector, combining them into an exhaustible and comprehensible list was difficult. Thirdly, many premises had multiple meters (as high as 14 in one premise) and collating the electricity bills across the year for them was an impossible task. Fourthly the variations within some categories of industries was so large that deriving a common norm for the same was infeasible.

The ultimate collation of the figure and thereafter discussions with experts, led to a parallel model building exercise on another set of secondary data as obtained from ASI, which is detailed below.

5.5.2 Model

The model for projecting the demand for electricity in this sector is based on the relationship between the demand for electricity (d_i) and the value of the output (v_i) in that industry (i). The consumption of electricity and the value of output as reported in the sample survey has been used to calculate the norm for this sector, given by c_i.

$$c_i = d_i / v_i$$

This norm thus gives us the amount of electricity consumed to produce output worth one rupee. This relationship would vary for each product and thus the norm has been calculated for each class of industry as per ASI classification (Table 5.15).

The above mentioned norms have been calculated as per the adjusted sample as mentioned above with the exception of the category 'Beverages, tobacco and tobacco products'. It would be useful to compare the aforementioned norms with the norms obtained from the ASI data for the year 1997-98. This is given in the table 5.15

Table 5.15 : Comparison of industrial consumption norms from survey data and ASI data

S. No.	Category	Norm from ASI data	Norm froms data
1	Food products	0.0177	0.0059
2	Beverages, tobacco and tobacco products	0.0091	
3	Cotton textiles	0.0638	0.0188
4	Wool, Silk and Synthetic fibre textiles	0.0757	0.0402
5	Jute hemp and mesta textiles		
6	Textile products (including wearing apparel other than footwear)	0.0381	0.0023
7	Wood and wood products, furniture and fixtures	0.0260	0.0074
8	Paper and paper products and printing publishing and allied industries	0.0809	0.1754
9	Leather and fur products	0.0207	0.0058
10	Rubber, plastic, petroleum and coal products	0.0097	0.0104
11	Chemical and chemical products (except products of petroleum and coal)	0.0328	0.0128
12	Non-metallic mineral products	0.1249	0.0038
13	Basic metals and alloys industries	0.0281	0.0217
14	Metal products and parts except machinery and transport equipment	0.0380	0.0127
15	Machinery and machine tools and parts except electrical machinery		0.0049
16	Electrical machinery apparatus appliances and supplies and parts	0.0229	0.0115
17	Transport equipment and parts	0.0093	0.0102
18	Other manufacturing industries	0.0294	0.0008
19	Others	0.0085	0.0207

It is observed from the table above that the norms as obtained from ASI data are significantly higher than the norms as obtained from the survey data. This is due to the non-availability of data on electricity purchased for the entire year of the

survey. As most respondents have not reported the electricity purchased for the entire year, the norm has been calculated by deriving the average monthly consumption using the data provided by the respondents. However, in this method, seasonal variations in the electricity consumption of the industries are not accounted for. Thus, the norm derived using the ASI data has been used for the purpose of deriving the demand for electricity for the sector.

A time series of the total value of output and net value added of all the units in the state in each industry class has been obtained from the 'Summary results Factory Sector' published by the Annual Survey of Industries. The data used is a time series over the period 1990-91 to 1996-97. It is observed that the percentage share of each class in the value of output of the industrial sector in the state has been consistent over this time period and no major structural shifts are seen on this account. This observation has been used to project the value of output in each sector for the current year.

Thus, multiplying out the norm for each industry class with the respective total value of output for the particular year one would arrive at the total demand for electricity in that class of industry. Aggregating across all classes one would arrive at the total demand for electricity in the industrial sector.

Thus, the methodology used to calculate the present consumption in this category may be summarized by the system of equations as given below

$$Norm = \frac{Total\ electricity\ consumed\ in\ the\ year}{Total\ value\ of\ output\ in\ the\ year} \quad \ldots (1)$$

$$Demand\ for\ electricity = Norm * Total\ value\ of\ output\ of\ the\ category \quad \ldots (2)$$

The above demand is exclusive of the demand for electricity met by captive power plants as the norm has been calculated on the basis of the electricity bills which gives the electricity purchased from the grid. Thus the total demand for electricity due to the industrial sector would be the sum of the above demand and the power generated by captive power plants. Captive generation is discussed later in the chapter.

·5.3 *Projection*

The demand for electricity for the future has been derived by using the methodology mentioned above. The norms used for each industry class are those

derived above with the effect of efficiency built in. Since the projections are over a horizon of 10 years, the assumption incorporated here is that there would be a marginal improvement in efficiency due to technological advancement in this period. An efficiency improvement ideally, would be the result of investments made by the industrial units in the state. It would be incorrect to assume the improvement as a one-time improvement in any particular year. It has therefore been assumed that there would be an efficiency improvement of 1% in each year starting FY2002, thus amounting to a 10% improvement in the next 10 years. It may be noted here that we would be considering scenarios of efficiency improvement as given in the following section.

The time series of the total value of output and net value added of all the units in the state in each industry class has been obtained from the 'Summary results Factory Sector' published by the Annual Survey of Industries which, has been used to derive the value of output for the future. The ratio of net value added to value of output has been derived for the years and found to be consistent over the past 3 years. The NSDP from the industrial sector is the sum of the net value added (at constant prices) of the various industry classes. The projections of NSDP from the industrial sector have been made as given in chapter 3 on secondary models. The percentage share of the net value added of the various classes in the NSDP from the industrial sector has been used to derive the net value added of the various sectors in the future. The ratio of net value added to value of output has been used to derive the value of output for the future, which in turn has been used to derive the electricity demand for the future.

Thus, using the norm, adjusted for efficiency improvements and the projection of the value of output for each class of industry, the demand for electricity has been projected following the model specified in equation (2). The sum for all classes would give the total demand for electricity for the industrial sector for the state.

It may be noted that this demand does not include the demand from captive sources. The captive generation in the state of Gujarat has been projected separately using data regarding the total captive generation in the state for the period FY1994 to FY2000. The total demand from industry on captive sources was derived by netting out the sale from captive sources to GEB. Thus the demand from captive sources for FY2000 would be the total generation from

captive power plants net of the sale from captive sources to the grid. This has been given in the table 5.16:

Table 5.16: Captive demand for the industrial sector in the State

	Total Generation (MU)	Sale to GEB (MU)	Demand from Captive sources (MU)
FY2000	11345	188	11037

It was observed that this demand from captive amounts to 50.27% of the total demand for electricity from the industrial sector as given in table 5.15. However, on an analysis of the installed capacity of various captive power plants in the state, it was found that the captive power plant operated by Reliance Industries accounts for 28.8% of the total captive capacity. Netting this capacity out, captive generation in the state would amount to 34% of the total demand for electricity in the state, which is more comparable with other states in the country. It may be noted at this stage that during the primary survey, 9 respondents reported that they were operating captive power plants and they did not have any plans for expansion of the same. On the other hand, 13 other respondents reported that they had plans of installing captive power plants in the near future. Thus, keeping the liberal captive power policy in the state it would be reasonable to assume that the captive power in the state (excluding captive capacity of Reliance Industries) would be 34% of the total demand in the future. Also, keeping in mind the growth rate of the industrial sector, it may be assumed that the demand for power from captive sources of Reliance Industries would grow at a rate of 2% per year. This has been added to the demand from other sources as derived above to get the total demand from captive sources. The growth rate of demand from captive derived using this method varies between 5.2% and 4.6%. Applying the growth rate for the respective years on the actual demand from captive sources for FY2000 we get the demand from captive sources in the state of Gujarat as given in table 5.16.

5.5.4 Result

Using the above methodology, the electricity demand for FY2000 has been derived as this would be used as the validation year. The comparison of the projections for the year is given below in Table 5.17.

Table 5.17: Consumption (MU) of industry as calculated for validation year.

	Actuals*	ASI model	Primary model
FY2000	11037	11889	11256
%age variation from actuals		7.72%	1.99%

* includes consumption from GEB, AEC and SEC as per the tariff orders/filings

Thus we see that the projection for the validation year using the primary model varies from the actuals for the year by 2%, which is acceptable statistically. Thus the model is validated. Thus the model is applied to obtain the demand for the industrial sector over the years.

The scenarios relevant to this sector are that of the effect of a variation in the rate of growth of the economy as reflected in the GDP, improvement in the efficiency of the machinery used, the change in the structure of the economy due to shift from industrial to services sector, and the impact of changes in the captive power policy. However, of all the possible scenarios, only two most relevant which are in conformation with the other sectors is addressed here, namely the business as usual scenario (with respect to NSDPI growth) and an efficiency improvement within that scenario.

Though a certain amount of improvement in efficiency has been already factored in to forecast the business as usual scenario, the conservation of electricity achievable with investments in this direction are much higher. An efficiency improvement of 20% over the next 10 years has been taken as a scenario to highlight the possible conservation of electricity. This scenario has been developed on the business as usual scenario and the total demand in this case is given in table 5.18 .

Table 5.18: Total demand for electricity (MU) in industry sector as forecasted

Year	Business as usual	Improvement in efficiency
FY2002	12808	12678
FY2006	16234	15380
FY2011	21779	19359

However the total demand for electricity due to the industrial sector in the state of Gujarat would be the sum of the demand from the various industrial units and the demand from the various captive sources in the state. Thus the total demand for electricity in the state is as given in the table 5.19.

Table 5.19: Total demand for electricity (MU) of Industry sector inclusive of captive consumption

Year	Demand from Industry (MU)	Demand for power from captive sources (MU)	Total Demand from Industry (MU)
FY2002	12808	10326	23134
FY2006	16234	12378	28612
FY2011	21779	15593	37372

It may be kept in mind that the total demand for the state of Gujarat as stated in the table 5.19 represents the amount of electricity that the industrial sector of the state would consume in that particular year. Thus, in the event of a less liberal captive power policy, the demand from captive sources would shift to the utility. This scenario has been discussed below. Also, in the event of lower tariffs and better quality of supply too, the demand from captive sources would shift to the utility.

It may be noted that the percentage of captive generation in the state of Gujarat is much higher than that in other states of the country. The main cause for this is said to be the liberal captive power policy in the state. However, it may also be noted that the rate of growth of industry in the state is consistently higher than the rest of the country. In the event of the captive power policy being made less liberal, the demand for power by the industry would shift to the utility. Further, during our survey many respondents stated that, in the event that the utility offers lower tariffs and better quality of supply, they would prefer to take power from the utility than to set up captive power plants. Thus the percentage of captive power in the total demand for power in the state would decline in the future in this scenario, though the total demand for electricity would remain the same as stated above.

Annex 5.1

	Jamnagar	Rajkot	Surendranagar	Bhavnagar	Amreli	Junagadh	Kachchh	Banskantha	Sabarkantha	Mahesana
Wheat	0 000506	0.000506	0.000506	0.000506	0.000506	0.001104	0.003372	0.001962	0.001962	0.009611
Rice	0.004865	0.004865	0.004865	0.004865	0.004865	0.004865	0.004865	0.004631	0.004631	0.005321
Jowar	0.000043	0.000043	0.000043	0.000043	0.000043	0.000043	0.000043	0.001557	0.001557	0.007142
Bajri	0.001812	0.001812	0.001812	0.001812	0.001812	0.001168	0.001812	0.002503	0.002503	0.010134
Maize	0.000454	0.000454	0.000454	0.000454	0.000454	0.000311	0.000311	0.000621	0.000621	0.000621
Gram	0.000448	0.000448	0.000448	0.000448	0.000448	0.001343	0.001343	0.001919	0.001919	0.001919
Other pulses	0.000257	0 000257	0.000257	0.002418	0.002418	0.000257	0.002418	0.000993	0.000993	0.003575
Sugarcane	0.005875	0.005875	0.005875	0.005875	0.005875	0 005875	0.005875	0.005875	0.005875	0.000524
Cotton	0 001155	0.001155	0.001155	0 001155	0.001155	0 001419	0.002798	0.003772	0.003772	0.007135
Groundnut	0 025100	0 025100	0 025100	0 025100	0.025100	0 002502	0 007734	0.002280	0.002280	0.002280
Sesame	0.001399	0 001399	0 001399	0 001399	0 001399	0 001399	0 001399	0.015029	0.015029	0.015029
Mustard	0 002014	0 002014	0 002014	0 002014	0 002014	0 002014	0 002014	0 002271	0.002271	0.006947
Other oilseeds	0.001081	0.001081	0 001081	0.001081	0.001081	0 000973	0.001846	0.000778	0.000778	0.013047

	Gandhinagar	Ahmedabad	Kheda	Panchmahals	Vadodara	Bharuch	Surat	Valsad	Dangs
Wheat	0.004905	0.003198	0.001434	0.001434	0.002036	0.000311	0.000199	0.000199	0.000199
Rice	0.011025	0.003060	0.002377	0.002470	0.002257	0.000811	0.000811	0.002562	0.002562
Jowar	0.001499	0.001570	0.002149	0.002149	0.002149	0.002149	0.002149	0.002149	0.002149
Bajri	0.003849	0.003479	0.002019	0.003440	0 007609	0.007609	0 007609	0.007609	0.007609
Maize	0.000621	0.000621	0.000259	0.000259	0.000259	0.000147	0.000147	0.000147	0.000147
Gram	0.001919	0.001919	0.000456	0.000456	0.000456	0.000456	0.000456	0.000456	0.000456
Other pulses	0.001216	0.001072	0.000776	0.000776	0.000776	0.000730	0.000730	0.000730	0.000730
Sugarcane	0.000524	0.000524	0.000524	0.000524	0.000524	0.001359	0.001359	0.001014	0.001014
Cotton	0.002189	0.002189	0.000717	0.000717	0.000717	0.001166	0.001166	0.001166	0.001166
Groundnut	0.007734	0.007734	0.007734	0.002280	0.002280	0.002280	0.002280	0.002280	0.002280
Sesame	0.015029	0.015029	0.015029	0.015029	0.015029	0.015029	0.015029	0.015029	0.015029
Mustard	0.002270	0.002270	0.002270	0.002270	0.002270	0.002270	0.002270	0.002270	0.002270
Other oilseeds	0.005254	0.005254	0.001072	0.007413	0.007413	0.001072	0.000329	0.000329	0.000329

Annexe:5.2

Average Consumption per Employee by Commercial sub-sector

Commercial Category	Consumption per Employee on annual basis (kWh/employee/year)
Communication	628.43
Educational Institutions	126.00
Finance, Insurance and Business Services	254.17
Medical Institutes	582.76
Restaurants & Hotels	632.20
Retail Trade	297.66
Storage & Warehousing	1263.02
Transport	225.34
Wholesale Trade	225.03

6 Supply side scenario

6.1 Introduction

The status of electricity supply vis-a-vis demand is one of the most important factors, which not only reflects the condition of the electricity sector, but also acts as an indicator to future investors. Investors in not only the electricity sector but also other industrial and commercial sectors carry out future planning based on such indicators. It thereby is a major determinant of the future macroeconomic condition of the economy. Gujarat being one of the most industrialised states in the country, the need of a well functioning and reliable power sector plays a vital role in the overall growth of the economy.

However to ensure availability of adequate power to maintain a balanced and sustainable system, the most crucial and important task is proper demand projection of electricity. This would not only be needed for supporting the investment plan of the economic activities in the other sectors, but more importantly for investment planning of the sector itself. Any mismatch in the system has very high economic and financial implication. In case of shortages, the state would lose in terms of economic activities that need to be foregone as well as lose out on future investors. On the other hand in case of surplus, the situation demands non-utilisation of already added capacity, leading to a sub-optimal economic and financial condition along with stranded costs.

Thus to wrap up the demand projection study an analysis of the supply side is also carried out to provide a holistic view of the sector. The supply side is assessed by analysing the data on existing generating plants and proposed capacity additions within the state as well as availability from the central station to the Gujarat system. However at the outset it needs to be noted that supply side assessment is an exhaustive study in itself. The assessment carried out here is merely a theoretical calculation, without addressing the practical nuances of the system. But at the same time it should also be realised that this exercise itself provides an indication of the probable surplus/ deficit situation in the sector.

6.2 Data Requirement

The Gujarat power system is supplied power from three distinct sources, namely, the generating stations belonging to the erstwhile GEB, the central generating stations and the IPPs. However the system also supports power from captive sources at times, but mostly the same is generated for self-consumption by the industries. Moreover the supply to the grid by these captive plants is erratic and only need based. Therefore the same cannot be projected and hence is not included in the calculations here, though information on captive was collected for the current year. Data regarding the current generation capacity and future capacity additions had been taken from the Gujarat Electricity Board. In particular, the following information/data has been collected from the GEB planning division:

1) Data regarding plants owned and operated by GEB, the installed capacity, year of commissioning of various units, the capacity in operation as on March 2001 (de-rated capacity), the plan (year and capacity) for de-commissioning of existing units, the station/unit-wise plant load factor (PLF) for the past 3-4 years and the generation (station/unit-wise) as on March 2001. The same information has been collected for IPPs/ private and others.

2) Data regarding Gujarat's share in central sector projects (plant name/ total capacity/ Gujarat's share/ fuel type), Gujarat's share in joint sector and any other projects (project/ total capacity/ Gujarat's share/ fuel type), the station/ unit-wise PLF for past 3-4 years, the station/unit-wise plant availability, and generation (station/unit-wise) as on March 2001.

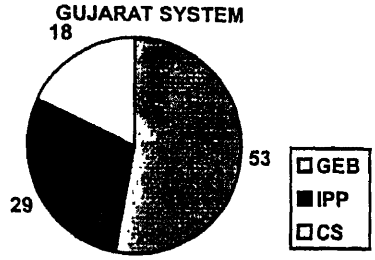
3) Data regarding the plan for capacity additions by the GEB was also collected, namely, the name of the project, the status, the capacity, the unit size configuration, the fuel to be used and the tentative year of commissioning. In the case of capacity additions by IPP/Private sector/CPSUs/Joint sector/others, data regarding Gujarat's share in central sector plants has also been collected.

In the following sections the first discussion is on the existing available capacity (as of 2000-01), followed by analysis on future capacity addition in Gujarat.

6.3 Current supply side analysis

Apart from available captive capacity, Gujarat power supply mainly comprises installed generating capacities under Gujarat Electricity Board, Ahmedabad

Chart 6.1: GENERATION MIX IN THE GUJARAT SYSTEM



Electricity Company and Independent power producers along with the share in central generating stations. As stated above, the total available capacity with Gujarat (8506 MW for the year 2000-01), includes 1532 MW of the allocated share of Gujarat from central sector stations contributing 18 per cent of the total capacity, while GEB own plants contributes 53% to the overall supply. The rest is taken care of by the IPPs. The share of each of these sources is depicted in the pie chart (Chart 6.1)

However to determine the supply from these capacities, the other important factor that needs to be assessed is their PLF. The information regarding the same and other details on existing generation capacity of GEB plants (fuel type, derated capacity, etc.) as on 2000-01 are shown below in table 6.1.

Table6.1 : GEB's plants as on 2000-01

Generation by GEB's Plants as of FY 01

Sl. No.	Plant	Units	Fuel type	Installed Capacity (MW)	Derated Capacity	Auxiliary consumption (%)	PLF (%)
1	Dhuvaran	4*63.5+2*140+2*27	Oil & gas	588	588	9.60%	50%
2	Wanakbon	6*210	Coal	1260	1260	9.50%	81%
3	Gandhinagar TPS	2*120+2*210	Coal	660	660	10.20%	58%
4	Ukai TPS	120*2+200*2+210	Coal	850	850	10%	72%
5	Utran	3*30+1*45	Gas	135	135	4.80%	61%
6	Sikka	120*2	Coal	240	240	10.50%	68%
7	KLTPS	2*70+75	Lignite	215	215	12.50%	51%
8	Ukai Hydro	75*4	Hydro	300	300	0.90%	25%
9	Kadana Hydro	4*60	hydro	240	240	0.90%	25%
10	Ukai Left bank canal	2*2.5	hydro	5	5		25%
11	Panam canal	2*1	hydro	2	2		25%
12	Utran old	1*45	coal	45	39	4.80%	61%
	Total			4540	4534	7.66%	57%

Source : GEB

Similar information has been also collected on the other major source of power in Gujarat i.e. the IPPs, which provides 29% of the total available capacity. In the year 2000-01 out of total available capacity of 8506 MW, capacity available with Gujarat from IPPs was 2440 MW. Various IPPs plants by fuel type, their installed capacity, de-rated capacity, capacity available with Gujarat Electricity Board, PLF of the various plants in the year 2000-01 are shown in table 6.2.

Table 6.2:IPPs Plants as on 2000 -01

S.No.	Plant	Units	Input	Installed Capacity (MW)	Derated Capacity	Capacity available to GEB	PLF %
1	AEC	3*110+4*9+1*20+1*24+ 2*32.5+1*35	Coal & gas	550	510	510	75%
2	GIPCL	3*32+1*49+105+55	Gas	305	305	160	52%
3	Essar	3*110+185	Naptha & gas	515	515	300	46%
4	GPEC	3*138+240	Gas & naptha	655	655	655	43%
5	GSECL G'nagar.5	1*210	Coal	210	210	210	73%
6	GSECL W	1*210	Coal	210	210	210	84%
7	GIPCL (M)	2*125	Lignite	250	250	250	52%
Sanction Holders							
1	GIPCL			145	145	145	52%
Total from IPPs				2840	2800	2440	52%
Total available capacity with GEB						8506	

It needs to be noted that PLF of IPPs depend heavily on the demand for electricity from Gujarat Electricity Board, which in turn is determined by the requirement of the grid at any point in time. Thus the low PLF (52%) is not necessarily due to the poor performance of the plants but can be contributed to the factor of low demand in the system.

The third major source of power for Gujarat, the share from central sector plants (NTPC and NPC), provides 18% of the total available capacity has been also detailed. The share from NTPC and NPC plants, their installed capacity, de-rated capacity, the GEB's share and average PLF of NTPC and NPC plants as obtained from GEB is shown below in table 6.3.

Table 6.3 Central Generating Station for 2000- 01

SL.No	Source	Installed Capacity (MW)	Derated Capacity	Capacity available to GEB (MW)	PLF(%
1	NTPC	5652	5652	1247	89%
2	NPC	760	730	285	82%
	Total	6412	6382	1532	

At the outset, it needs to be mentioned that in the year 2000-01, average PLF of NTPC and NPC plants was 89% and 82% respectively whereas the average PLF of GEB own plants was 57%, which indicates that there is scope for improvement.

6.4 Future projects and analysis

The liberalization process initiated in the year 1991 and the new power policy announced by the Government in October 1991 have redrawn the contours of power industry in the country and also in Gujarat. Participation of the private sector in the hitherto exclusive domain of the Government in power generation, transmission and distribution is bringing in fundamental changes in the sector. Thus, the end of eleventh plan (2012) is expected to witness a very different scenario with patterns of ownership of assets significantly altered. The emerging Independent Power Producers (IPPs) and expansion of Central Sector Stations like NTPC will create a competitive environment. Whereas state plants due to funds constraints will restrain their expansion. Most of these emerging power producers have drawn up their next ten-year plan on capacity additions.

In the coming decade, we would see similar trend in Gujarat where the share of GEB's plants in total capacity would come down from 51% to 32% whereas share of central sector plant would increase from 18% to 38%. By the year 2011-12 the new projects would add up to over 16629 MW capacity. This includes the most awaited 1450 MW Sardar Sarover Narmada Power Limited (SSNPL).
We would discuss the future additions in installed capacity of Gujarat in greater detail. We would first look at the future GEB plants, followed by future IPPs and central sector plants along with GEB's share in them.

6.4.1 GEB plants

The proposed plants of GEB are Sikka with 500 MW capacity, KLPTS Panandhro with 75 MW capacity, Kandla with 250 MW. The proposed year of commissioning of Sikka thermal power station is 2005-06 for the first unit (250 MW) and 2006-07 for the second unit (250 MW). The proposed year of commissioning for the KLTPS thermal power station is 2005-06 and for the Kandla thermal power station is 2008-09. The fuel type for Sikka and Kandla plants are imported coal and for KLTPS it is lignite. The project name, number of units, fuel type, proposed year of commissioning and others details are attached in Annex 6.1.

In general progress on various project has been slow. Still if we go by the plan, the proposed plants of the GEB and MW capacity addition that would benefit Gujarat in the short term (2002-03), medium term (2006-07) and in the long term (2011-12) are shown below in the table 6.4.

Table 6.4 GEB Proposed Plants

Proposed GEB Plants	Fuel type	2006-07	2011-12
Sikka TPS 2*250 Mw Unit 3&4	Imported coal	500	
KLTPS Panadhro Unit No.4	Imported Coal	75	
Kandla TPS	Lignite		250

6.4.2 Future addition through IPPs

Since liberalization, the Gujarat policy has been very conducive for private investments and has been seeking investments in the power generation. As many as eight Independent power producers have shown interest in setting up power generation plants. If they go by their plan, at the end of 2009-10, Gujarat would be benefited by the additional capacity of 2841 MW.

Based on the information provided by the GEB planning department as well as detailed discussions held with the GEB, the details of additional generation capacity likely to give benefits during short term, medium term and in long term with their fuel type are shown in table 6.5 below. Other details regarding tentative year of commissioning etc. are attached in annex 6.1.

Table 6.5 IPPs Proposed plants

Proposed Plants	Fuel type	2002-03	2006-07	2011-12
IPP				
Gas based CCPP at Hazira (GSEG)	Natural Gas	156		
Aknmota-GMDC	Lignite	125	125	
Jamnagar-RPL	Petcock		500	
Ghogha-RPL 3*125 MW	Lignite		375	
Dhuvaran-GSECL Gas based CCPP	Gas		110	
GSEG Expansion Gas Based CCPP	Gas		200	
Utran CCPP Gas Based CCPP	LNG/ Natural gas			300
Gadhinagar Extn.Gas based CCPP	LNG			700

At the outset, it needs to be mentioned that most of the IPPs plants are in nascent stage of negotiations for suitable fuel linkages and other clearances.

6.4.3 Central Sector plants and GEB's share

The central generating stations provide more than 30% of the total installed capacity in India. The central generating stations include plants of Nuclear Thermal Power Corporation, National Hydro Power Corporation and Nuclear Power Corporation. Among them NTPC is planning to add another 20000 MW by year 2012[a]. Out of this, GEB will have share in 10000 MWs. This includes developing the 2000 MW imported coal based Pipavav project as "mega" project announced under mega power policy. Other future additions of NTPC that would benefit Gujarat are NTPC Bihar (1000 MW), Sipat stage 1 (1980 MW), Hirma project (3960 MW), Sipat stage II (660 MW), Vindychal stage III (500 MW). Apart from NTPC plants, Sardar Sarover Nagar Nigam Limited (SSNNL) 1450 MW plant is in culmination stage and tentatively by the year 2002-03 would benefit Gujarat by providing additional capacity of 232 MW.

The share of Gujarat in the proposed central sector plants that would benefit in the short term, medium term and in the long term are shown in the table 6.6. Greater details have been provided in the Annex 6.1.

Table 6.6: Proposed central generating stations

Central Sector GEB Share	2002-03	2006-07	2011-12
Sardar Sarovar (1450MW)	40	192	
NTPC Bihar		1000	
Sipat Stage-I (3*660)		475	
SEAP (Hirma Project) (6*660)		700	
NTPC Sipat Stage II (1*660)			300
NTPC Vindychal Stage III (2*250)			500
Pipavave (2000)			1500

Summing up the above discussion, additional 8123 MW of capacity would benefit Gujarat in next twelve years. Out of which 825 MW would be provided by Gujarat Electricity Board, 2591 MW would be provided by Independent power producers and 4707 MW would be provided by Central sector plants.

The future sources of supply in the short, medium and long term are shown below in table 6.7.

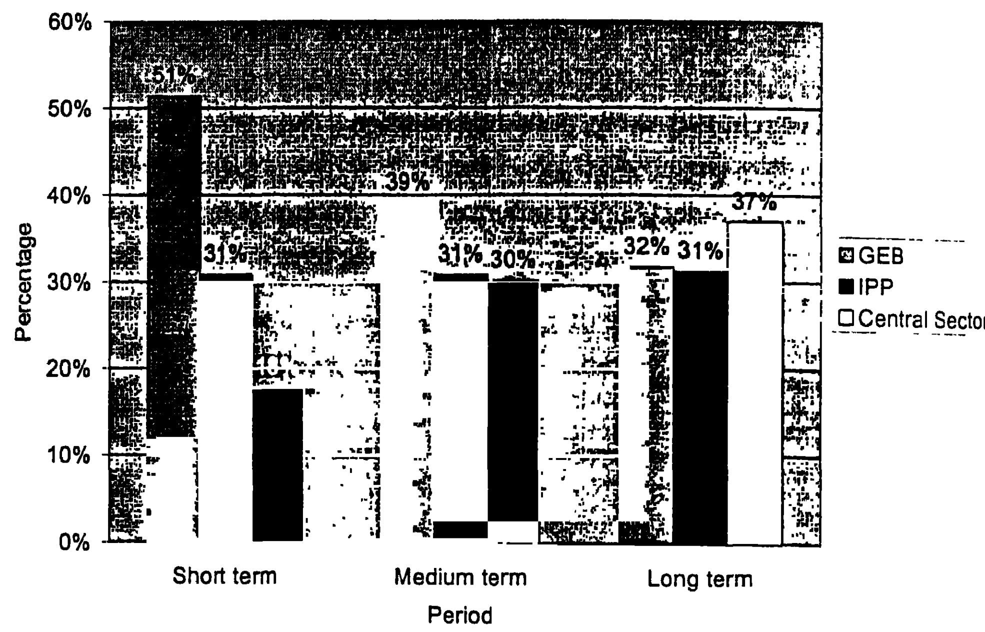
[a] www.ntpc.co.in

Table 6.7: Future installed capacity at the end the short term, medium term and long term

	Short Term	Medium Term	Long Term
Gujarat Electricity Board	4534	5109	5359
Independent Power Producers	2721	4031	5031
Central Sector Plants	1572	3939	6239
Total MW available with GEB	8827	13079	16629

The share of various sources could be seen below in the chart 6.2.

Chart 6.2 Share of various plants in total capacity



6.5 Supply projection

Energy Supply projection (MU)

The projected installed capacities thus available from the secondary sources provide only the base for the calculation of energy availability in the system. The megawatt thus projected are then multiplied by the PLFs to obtain the energy generated from the plant. To calculate the energy sent out, auxiliary consumption would be subtracted from the energy generated. There are certain assumptions made with respect to the PLF & auxiliary consumption, namely,

Assumption A: PLF for the proposed plants has been taken by using norms set by Central Electricity Authority. The norms used for future thermal and gas plants are summarized below in the table 6.8. Though these norms are

developed for tariff calculations, assuming the same would be a pessimistic assessment of the scenario.

Table 6.8 : Average PLF norms for future power projects by fuel type and size

Sl.No.		Base case
1.	Thermal coal (>500 MW)	75.00%
2.	Thermal coal (<500 MW)	68.40%
3.	Thermal (gas)	68.40%

Assumption B: PLF for the existing plants is determined by taking weighted average of PLF for past three years. The PLF taken for existing GEB's plants, IPPs and central sector plants are summarized below in the table 6.9:

Table 6.9: Average PLF for the existing plants

Sl.No.	Plant	Three year Average PLF
GEB's own plants		
	1 Dhuvaran	49%
	2 Wanakbon	80%
	3 Gandhinagar TPS	60%
	4 Ukai TPS	63%
	5 Utran	77%
	6 Sikka	71%
	7 KLTPS	52%
	8 Ukai Hydro	25%
	9 Kadana Hydro	25%
	10 Ukai Left bank canal	25%
	11 Panam canal	25%
	12 Utran old	61%
IPPs Plant		
	1 AEC	74%
	2 GIPCL	68%
	3 Essar	60%
	4 GPEC	59%
	5 GSECL G'nagar.5	71%
	6 GSECL W	43%
	7 GIPCL (M)	68%
Central Sector plants		
	1 Korba	89.3%
	2 Vindhyachal I & II	89.3%
	3 Kawas	89.3%
	4 Gandhar	89.3%
	5 Tarapur	79.2%
	6 Kakrapur	79.2%

Assumption C: Auxiliary consumption for the proposed plants has been taken by using norms set by Central Electricity Regulatory Commission. The norms used for future thermal and gas plants are summarized below in the table 6.10:

Table 6.10: Auxiliary consumption norms for future power projects by fuel type

Sl.No.	Fuel type	Base case
1.	Coal plant	8.5%
2.	Gas plant	2.5%

Assumption D: Auxiliary consumption for the existing plants is assumed to be the same as auxiliary consumption for year 2000-01. The auxiliary consumption taken for existing GEB's plants, IPPs and central sector plants are summarized below in the table 6.11:

Table 6.11: Auxiliary consumption for the existing power plants

S.No.	Plant	Auxiliary Consumption for the year 2000-01
GEB plants		
1	Dhuvaran	9.6%
2	Wanakbori	9.5%
3	Gandhinagar TPS	10.2%
4	Ukai TPS	10.0%
5	Utran	4.8%
6	Sikka	10.5%
7	KLTPS	12.5%
8	Ukai Hydro	1.0%
9	Kadana Hydro	1.0%
10	Ukai Left bank canal	1.0%
11	Panam canal	1.0%
12	Utran old	9.5%
IPP plants		
1	AEC	7.0%
2	GIPCL	2.9%
3	Essar	2.8%
4	GPEC	2.9%
5	GSECL G'nagar.5	8.5%
6	GSECL W	9.0%
7	GIPCL (M)	10.0%
Central generating stations		
1	Korba	7.0%
2	Vindhyachal I & II	7.0%
3	Kawas	7.0%
4	Gandhar	7.0%
5	Tarapur	7.0%
6	Kakrapur	7.0%

Taking the above assumptions, the supply situation in Gujarat at the end of short term, medium term and in long term is calculated as shown in the table 6.12.

Table 6.12 : Energy availability at the end of short term, medium term and long term

Sl.No.		Capacity available (MW)	Units available (MU)
1.	Short Term (2002 03)	8827	46649
2.	Medium Term (2006-07)	13079	70585
3.	Long Term (2011-12)	16629	90936

Peak Supply projections (MW)

The peaking availability has been calculated using norms set by the CEA (Central Electricity Authority) for exiting as well as future thermal projects (coal & gas). In the case of hydro projects, the peaking availability from hydro projects is worked out as per the CEA norms. The norms used for existing and future hydro and thermal projects are summarised in Table 6.13.

Table 6.13 : Peaking availability norms for future and exiting power projects by fuel type and size

		Net peaking availability factor (%)	
Sl.No.		Future	Existing
1.	Hydro	86.5	86.5
2.	Coal (>=500 MW)	73	73
	Coal (<500 MW)	71	71
	Coal (<=200 MW)	71	68
3.	Gas	71	74

Applying the above norms for the various existing and anticipated future plants, net peaking availability at the end of short, medium and long terms is calculated as shown in the Table 6.14

Table 6.14 : Net Peaking availability at the end of short, medium and long term

Sl.No.		Capacity available (MW)	Net peaking availability (MW)
1.	Short Term (2002-03)	8827	6487
2.	Medium Term (2006-07)	13079	9590
3.	Long Term (2011-12)	16629	12164

Before closing the discussion on supply projections, it may be recognised that PLF and net peaking availability (MW) for some of the plants would be low. For example, most of the NTPC thermal plants operate at an availability of 80-85 per cent.

6.6 T&D loss assessment

Demand for electricity at the consumer end has been assessed in chapter 3 and chapter 5 based on secondary and primary models respectively. However the values obtained from these models, are simply the consumption figure, but to figure out the supply requirement i.e. the generation requirement at the busbar the T&D loss in the system needs to be included.
As per the study on T&D loss, titled " Gujarat Transmission &Distribution Loss Estimation", done by TERI, estimated T&D loss in the GEB region is about 28.75% for the year 2001-02. For AEC and SEC T&D loss for the year 2001-02 was around 17% and 14% respectively. Considering these numbers, weighted average of three utilities is worked out and T&D loss for the state comes out to be 26.84%. For the future, certain assumption on T&D losses have been considered to arrive at total energy requirement at the busbar.

As per the TERI study on T&D loss estimation mentioned above , the transmission losses in the state is only 8.3% (for GEB area only), whereas, majority of the losses (around 20%) are due to commercial malpractice. In a situation like this it would not be financially practicable for the state to go for reduction in technical losses as the amount of investment that would be required appears to be much higher compared to the marginal impact on overall T&D loss reduction. On the other hand commercial losses in the form of illegal connection, improper billing and so on can possibly be brought down only through proper governance.

Discussing with experts and officials of GEB it was brought to our knowledge that considering the present status of losses, the overall T&D losses would be targeted to be brought down to a reasonable and achievable level of around 17-18% over a period of 10 years. A realistic assumption would be that T&D losses would reduce initially at an increasing rate and beyond a certain optimum rate of reduction, it would gradually diminish. Accordingly in the initial year, i.e. 2002-03, T&D losses are assumed to be reduced by 0.5% from the level of 26.84% as per the TERI study and in the next year losses are assumed to be reduced by 1% from the previous year level. Thereafter a further increase in the rate of reduction by 1.5% every year is assumed till 2006-07 beyond which it is assumed to be falling. Accordingly in 2006-07 the percentage of loss would be 21.34%. Thereafter it is assumed that the rate of reduction in losses would gradually fall. Thus the assumption made is that in 2007 and 2008 losses would

be reduced by 1.0% each year. Thereafter from 2009 onwards a further fall in rate of reduction in losses to 0.5% on yearly basis is assumed to be followed until the desired level of around 17-18% is reached. Accordingly T&D losses would reduce to 17.84% at the end of 2011-12. The assumed T&D loss at the end of short term, medium term and long term is shown in Table 6.15:

Table 6.15: T&D loss scenario

	Short Term (2002-03)	Medium Term (2006-07)	Long Term (2011-12)
T&D loss	26.84%	21.34%	17.84%

SL. No.	Name of Project			Capacity MW	Year of commissioning										
	GEB Projects	Fuel type	Owner		2001-02	2002-03	2003-04	2004-05	2005-06	2006-07	2007-08	2008-09	2009-10	2010-11	2011-12
1	Sikka TPS 2*250 MU Unit 3&4	Imported Coal	GEB	500					250	250					
2	KLTPS Panadhro Unit No.4	Lignite	GEB	75					75						
3	Kandla TPS	Imported Coal	GEB	250								250			
	Total GEB				0	0	0	0	325	250	0	250	0	0	0
	IPP Projects														
4	Gas based CCPP at Hazira	Natural Gas	GSEG	156	156										
5	JamnagarL	Petcock	RPL	500					500						
6	Aknmota	Lignite	GMDC	250		125	125								
7	Ghogha- 3*125 MW	Lignite	RPL	375					125	250					
8	Dhuvaran- CCPP	Gas	GSECL	110			110								
9	Utran CCPP	LNG / NG	GSECL	300							300				
10	Gadhinagar Extn. CCPP	LNG / NG	GSECL	700								300	400		
11	GSEG Expansion CCPP	Gas	GSEG	200						200					
	Total IPP				156	125	235	0	625	450	300	300	400	0	0
	Central Sector (Share)			Share of GEB											
12	Sardar Sarovar (1450MW)	Hydro	SSNNL	232		40	192								
13	Pipavave (2000)	Imported Coal	NTPC	1500							500	1000			
14	NTPC Bihar	Coal	NTPC	1000						1000					
15	Sipat Stage-I (3*660)	Coal	NTPC	475					475						
16	SEAP (Hirma Project) (6*660)	Coal	NTPC	700					700						
17	NTPC Sipat Stage II (1*660)	Coal	NTPC	300									300		
18	NTPC Vindychal-III (2*250)	Coal	NTPC	500										500	
	Total Central Sector				0	40	192	0	1175	1000	500	1000	300	500	0
	Year Wise Addition Installed Capacity (MW)				156	165	427	0	2125	1700	800	1550	700	500	0
	Total available capacity by the end of each year				8662	8827	9254	9254	11379	13079	13879	15429	16129	16629	16629

7 Conclusion

7.1 Introduction

The previous chapters provide a detailed analysis of the demand for electricity on a sectoral basis. As seen, the analysis is carried out both on the basis of purely secondary data as well as by applying end-use methods through a survey exercise. Since forecasting techniques have various uncertainties involved due to the dependence on factors both economic and structural, which fluctuate over time, hence, wherever possible alternative scenarios have been developed. [illegible] can be seen in [illegible] Besides demand, assumption on transmission and distribution losses have also been made – which when added to the consumption demand provides the generation requirement at the busbar. Thereafter an academic supply side analysis is carried out to obtain the future surplus/deficit scenario.

This chapter summarises all the scenarios that have been developed in all the previous chapters to provide the probable need of the future. However it needs to be reiterated again that these analyses are based on secondary and primary observations, which due to approximation might not provide the exact numbers, but are good indicators for future policy and investment decisions.

7.2 Secondary model summary

The secondary model as discussed in chapter 3 comprises two alternate models developed namely, structural and intensity models. Again within each of these models, three scenarios have been projected for most of the sectors based on the varying assumptions of the growth in NSDP. Since all the sectoral projections in both the models are ultimately linked to the sectoral NSDP, three alternate NSDP growth rates (BAU, moderate and optimistic) result in three scenarios of sectoral NSDP for each sector. Only agriculture sector in the structural model has one scenario, given that the explanatory variable considered here is pumpsets energised and not sectoral SDP. To arrive at the total consumption estimate in the state, the estimated sectoral demand is aggregated and a further 3.25% added to account for consumption due to railway traction, public lighting

and public water works. Annex 7.1 provides the sectoral consumption and the total consumption in the three scenarios developed using the two model specifications- structural & intensity. The total demand under the two specifications and three scenarios at the end of short term (2002), medium term (2006) and long term (2011) is separately provided in the Table 7.1 and Table 7.2.

Table 7.1: Consumption estimates (MU) using Structural models [†]

	STRUCTURAL		
	Scenario 1	Scenano 2	Scenario 3
FY2002	36409	36581	37173
FY2006	42387	43186	46089
FY2011	51336	53412	61583

Table 7.2: Consumption estimates (MU) using Intensity models [†]

	INTENSITY		
	Scenano 1	Scenano 2	Scenano 3
FY2002	29973	30255	31217
FY2006	36080	37078	40656
FY2011	44920	47172	55736

As evident from the above tables, the intensity model provides a more pessimistic scenario vis-à-vis the structural model. In all the three years i.e. short, medium and long term, Scenario 3 (i.e the optimistic scenario) under structural model provide the highest demand figures (table 7.1). The demand in the long term in this scenario is a little above 61,000 MUs. The least demand is projected by the BAU scenario under intensity model (Scenario 1 as per table 7.2), which stands at a little below 45,000 MUs.

This consumption figure basically reflects demand at the consumer end and does not include the T&D loss figures as estimated on the basis of certain assumptions detailed in Chapter 6. Incorporating the T&D loss numbers in structural and intensity model estimates, the demand at the generation busbar is calculated and the same is given in Table 7.3 and Table 7.4.

[†] inclusive of the assumed 3.25% share of railway traction, public lighting and public water works

Table 7.3: Estimated Demand (MU) at the generation busbar under different scenarios by using Structural models

	STRUCTURAL MODEL			
	Scenario 1	Scenario 2	Scenario 3	T&D Loss Assumption
FY2002	46181	46400	47151	T&D loss at 26.84%
FY2006	51433	52403	55925	T&D losses at 21.34%
FY2011	60495	62941	72569	T&D losses at 17.84%

Table 7.4: Estimated Demand (MU) at the generation busbar under different scenarios using Intensity models

	INTENSITY MODEL			
	Scenario 1	Scenario 2	Scenario 3	T&D Loss Assumption
FY2002	38018	38375	39595	T&D loss at 26.84%
FY2006	43799	44991	49333	T&D losses at 21.34%
FY2011	52933	55588	65680	T&D losses at 17.84%

7.3 Primary model summary

The primary model developed result in a new set of consumption and demand or energy requirement figures. These estimates developed on the basis of norms arrived at from the survey results provide consumption figures under two distinct scenarios developed. One scenario which assumes a business as usual set up, while the alternate scenario is one where an efficiency improvement is expected in the commercial sector and the industry is expected to grow at a an optimistic growth rate. Thus the total consumption arrived under these two scenarios is presented in the table 7.5.

Table 7.5: Consumption estimates (MU) by using primary models[ŧ]

	Scenario 1	Scenario 2
FY2002	34630	34480
FY2006	40870	39965
FY2011	48919	46391

Adding the T&D loss estimates to the consumption figure will give us the demand estimates at the busbar (as shown in Table 7.6).

[ŧ] inclusive of the assumed 3.25% share of railway traction, public lighting and public water works

Table 7.6: Estimated Demand (MU) at the generation busbar under different scenarios using primary models

	DEMAND		
	Scenario 1	Scenario 2	T&D Loss Assumption
FY2002	43925	43734	T&D loss at 26.84%
FY2006	49591	48493	T&D losses at 21.34%
FY2011	57647	54667	T&D losses at 17.84%

7.4 Peak demand assessment

The energy requirement in the system as obtained from the secondary and primary model, however provides only a partial depiction of the system. To obtain a better understanding, the corresponding peak demand also needs to be taken into consideration. However for calculating the peak demand, knowledge of the load factor of the system is vital. Determination of the same is an intensive exercise and a separate analysis needs to be undertaken. For the purpose of this study, however, the load factor is calculated on the basis of the EPS data of energy requirement and peak demand (Table 7.7).

Table 7.7: The load factor

EPS	Energy requirement (MU)	Peak Demand (MW)	Load Factor
FY2002	49141	8524	65.81%
FY2006	61683	10605	66.40%
FY2011	81615	14031	66.40%

The load factor thus calculated when applied on the demand data as calculated through secondary and primary models, results in corresponding peak demand, which are provided in the table below (Table 7.8).

Table 7.8: Peak demand estimation (in MW)

SECONDARY	STRUCTURAL MODEL			
	Scenario 1	Scenario 2	Scenario 3	T&D Loss Assumption
FY2002	8011	8049	8179	T&D loss at 26.84%
FY2006	8843	9009	9615	T&D losses at 21.34%
FY2011	10400	10821	12476	T&D losses at 17.84%
SECONDARY	INTENSITY MODEL			
	Scenario 1	Scenario 2	Scenario 3	T&D Loss Assumption
FY2002	6595	6657	6868	T&D loss at 26.84%
FY2006	7527	7735	8482	T&D losses at 21.34%
FY2011	9100	9557	11291	T&D losses at 17.84%

PRIMARY			
	Scenario 1	Scenario 2	T&D Loss Assumption
FY2002	7619	7586	T&D loss at 26.84%
FY2006	8526	8337	T&D losses at 21.34%
FY2011	9910	9390	T&D losses at 17.84%

7.5 TERI Recommendation and Conclusion

The demand and supply analysis carried out in the study provides an indication of the future surplus/ deficit condition of the state, besides providing an estimation of the probable future demand in the state.

The consumption as calculated under the various scenarios of both secondary and primary models, when compared to the EPS projection is much lower. A similar difference is observed even in the energy requirement values as calculated in the study vis-à-vis the EPS values.

The supply analysis carried out is based on two broad assumptions. One is a assumption regarding the year of commissioning[a] of future plants and the other is pessimistic assumption regarding the PLF of various plants. For example the supply calculation for the new capacities added is based on low PLFs, which are adopted as per the tariff setting norms. Even then the state is expected to have a surplus situation in the short, medium and long term in all the scenarios. However, if the availability factor is assumed in the supply calculation, as the case should be ideally, given that most NTPC thermal plants operate at an availability of 80-85 per cent, much above the 68.5 per cent PLF of the tariff norm, the surplus would be much higher. As per the current calculation the surplus ranges from a low of 6.2 per cent to a high of 66.3 per cent.

Among the twelve different models tried the results obtained from the primary model gives us the best fit. The forecasts under the 'Efficiency improvement scenario' vis-à-vis the 'Business as usual scenario' for the short, medium and long run developed under primary models are presented in table 7.9 and estimates for the entire forecast period are presented in annexe 7.1. The energy

[a] The year of Commissioning is according to the information provided by the GEB planning division held and discussion with the GEB officials. However, it may be noted that some of these future plants are running behind schedule.

requirements under these two most realistic scenarios are compared with the 16th EPS demand requirement and GEB pessimistic anticipated energy supply.

Table 7.9: Energy Demand-Supply Gap (MU)

	Model I (MU)	Model II (MU)	EPS projection (MU)	Anticipated GEB Supply (MU)	Anticipated GEB Supply and Model I projections	Anticipated GEB Supply and Model II projections	EPS and Model I projections	EPS and Model II projections
	Demand	Demand	Supply	Supply	Surplus (%)	Surplus (%)	Surplus (%)	Surplus (%)
FY2002	43925	43734	49141	46649	6.2	6.7	11.9	12.4
FY2006	49591	48493	61683	70585	42.3	45.6	24.4	27.2
FY2011	57647	54667	81615	90936	57.7	66.3	41.6	49.3

Further peak demands under these two scenarios are compared with the 16th EPS peak projections and GEB pessimistic anticipated net peaking availability, which is also presented in Table 7.10.

Table 7.10: Peak Demand-Supply Gap (MW)

	Model I (MW)	Model II (MW)	EPS projection (MW)	Anticipated GEB Supply (MW)	Anticipated GEB Supply and Model I projections	Anticipated GEB Supply and Model II projections	EPS and Model I projections	EPS and Model II projections
	Peak Demand	Peak Demand	Peak Supply	Peak Supply	Deficit / Surplus (%)	Deficit / Surplus (%)	Deficit / Surplus (%)	Deficit / Surplus (%)
FY2002	7619	7571	8524	6487	-15	-14	12	12
FY2006	8526	8323	10605	9590	12	15	24	27
FY2011	9910	9324	14031	12164	23	29	42	49

In conclusion it may be stated, that given the consumption trend, the supply options i.e. the plans of future additions needs to be re-looked. Moreover, the consumption analysis based on econometric modeling is relevant in the medium and long term, while for the short term trend analysis proves to be more reliable. Again, the end-use analysis if based on reliable data is capable of capturing the unrestricted demand of the state. Thus the accuracy of the results could be further improved if the reliability / precision of the data obtained improves.

Annexe 7.1 Primary Model Results

Scenario 1 Business As Usual	Domestic Sector MU	Commercial Sector MU	Industry Sector MU	Agriculture Sector MU	TOTAL (inclusive of 'others' category) MU	T&D Loss Assumption	Estimated Demand at Generation Bus bar MU
FY2001	4523	1610	12068	13684	32955	26.84%	41800
FY2002	4643	1636	12808	14418	34630	26.84%	43925
FY2003	4764	1663	13592	15040	36237	25.84%	45601
FY2004	4884	1691	14423	15472	37695	24.34%	46870
FY2005	5004	1719	15303	15941	39242	22.84%	48205
FY2006	5124	1747	16234	16436	40870	21.34%	49591
FY2007	5244	1774	17221	16904	42525	20.34%	51175
FY2008	5364	1802	18265	17283	44149	19.34%	52687
FY2009	5484	1829	19371	17543	45713	18.84%	54326
FY2010	5605	1856	20541	17740	47280	18.34%	55951
FY2011	5725	1884	21779	17941	48919	17.84%	57647

Scenario 2 Improvement in Efficiency	Domestic sector (MU)	Commercial sector (MU)	Industry sector (MU)	Agriculture sector (MU)	TOTAL (inclusive of 'others' category (MU)	T&D Loss Assumption	Estimated Demand at Generation Bus bar (MU)
FY2001	4523	1610	12068	13684	32955	26.84%	41800
FY2002	4643	1620	12678	14418	34480	26 84%	43734
FY2003	4764	1647	13315	15040	35933	25 84%	45218
FY2004	4884	1674	13977	15472	37216	24 34%	46275
FY2005	5004	1698	14665	15941	38561	22 84%	47369
FY2006	5124	1726	15380	16436	39965	21 34%	48493
FY2007	5244	1753	16122	16904	41367	20 34%	49781
FY2008	5364	1776	16891	17283	42702	19.34%	50960
FY2009	5484	1803	17687	17543	43946	18.84%	52225
FY2010	5605	1830	18510	17740	45153	18.34%	53434
FY2011	5725	1858	19359	17941	46391	17.84%	54667

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